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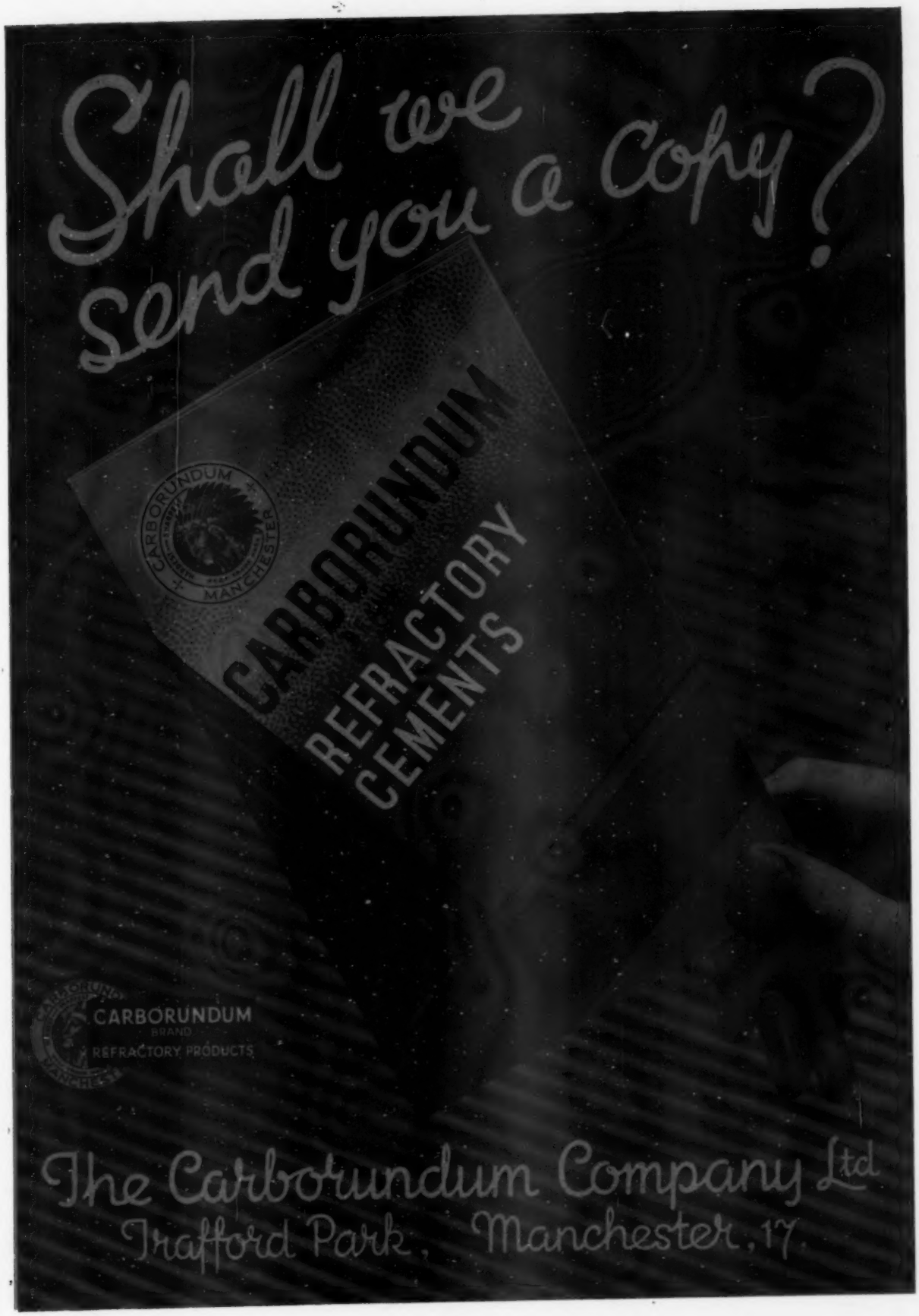
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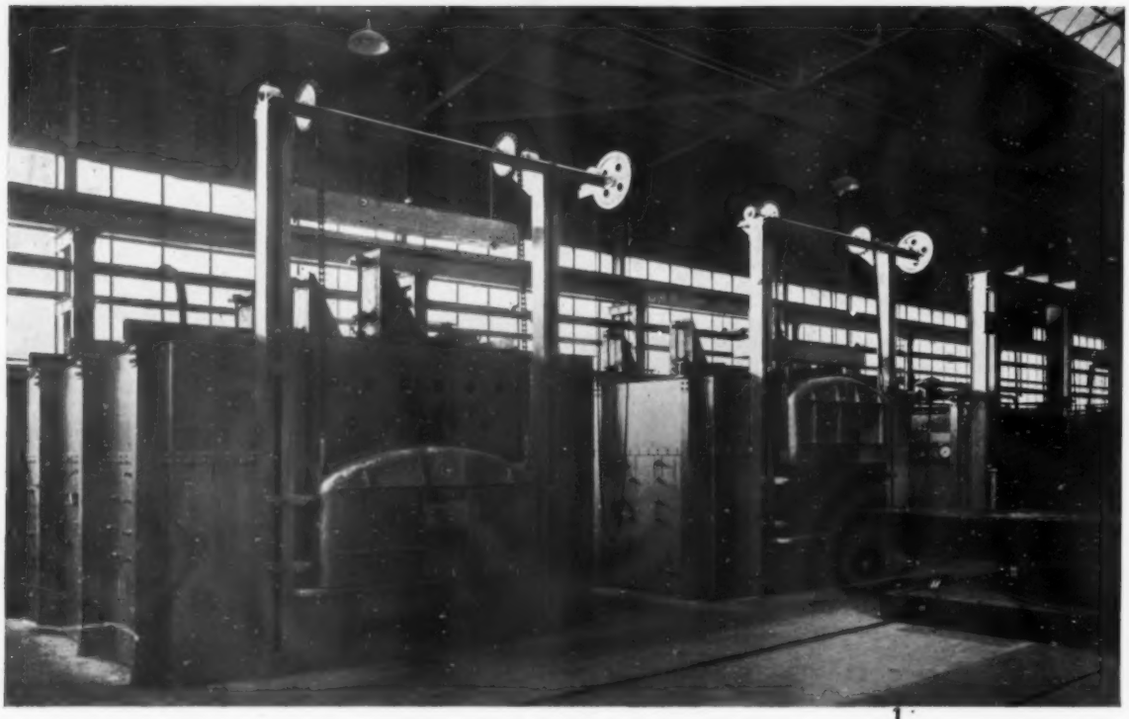

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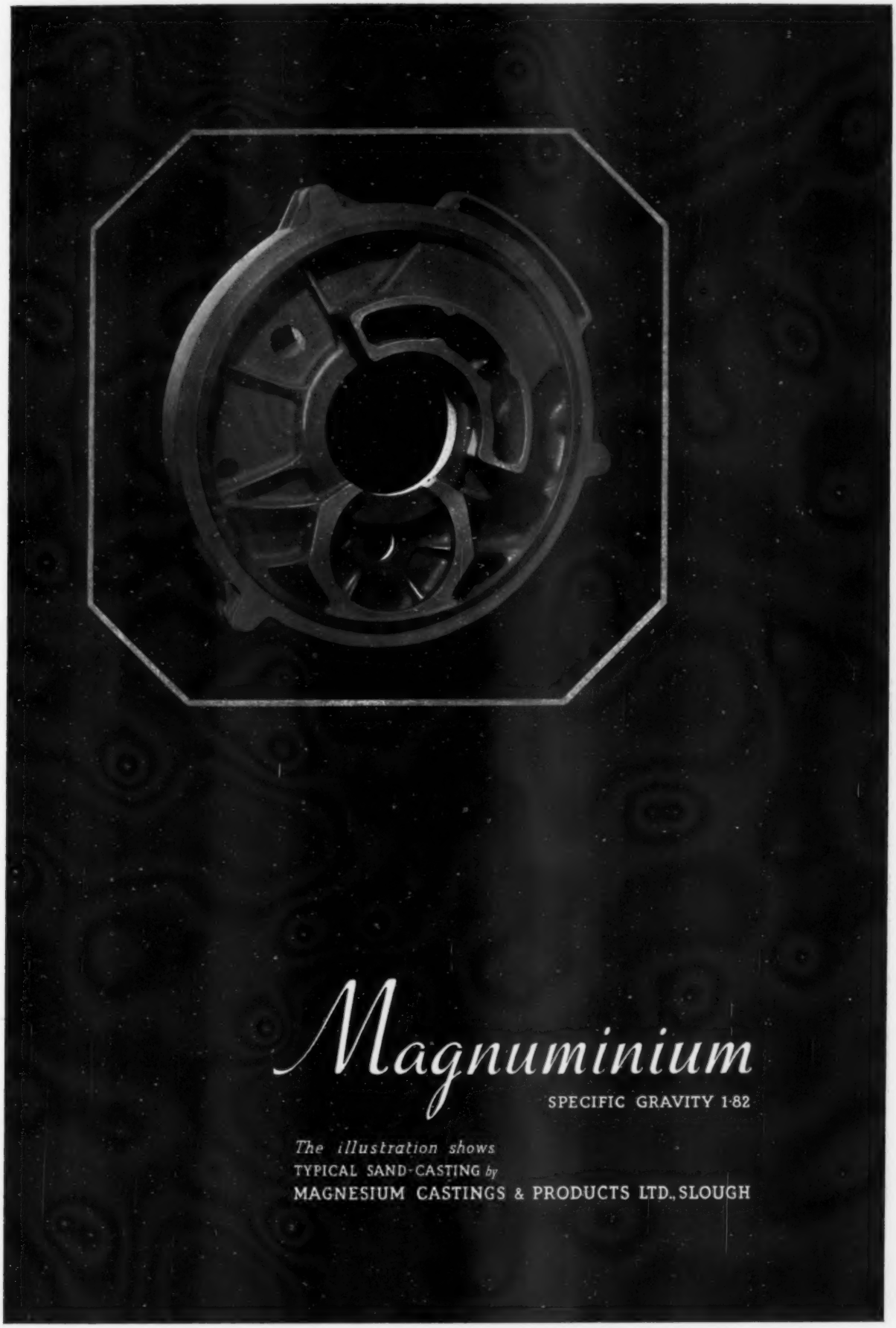
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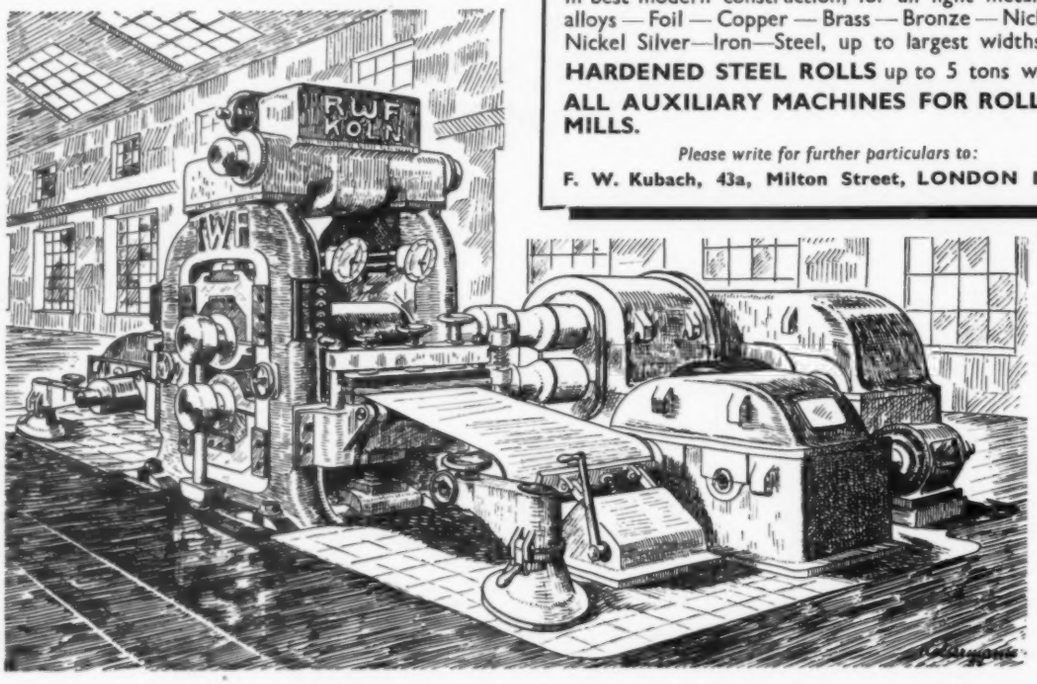

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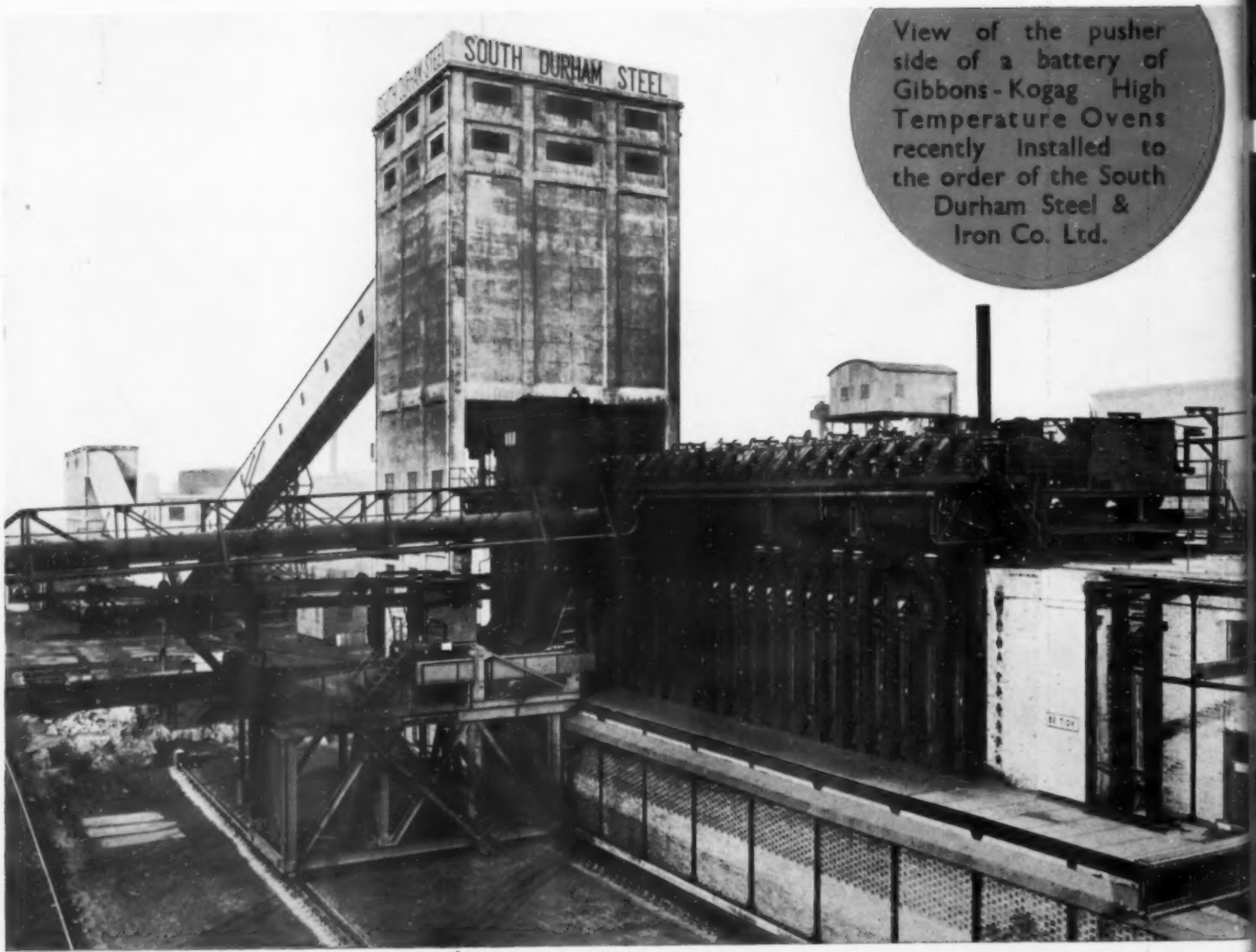

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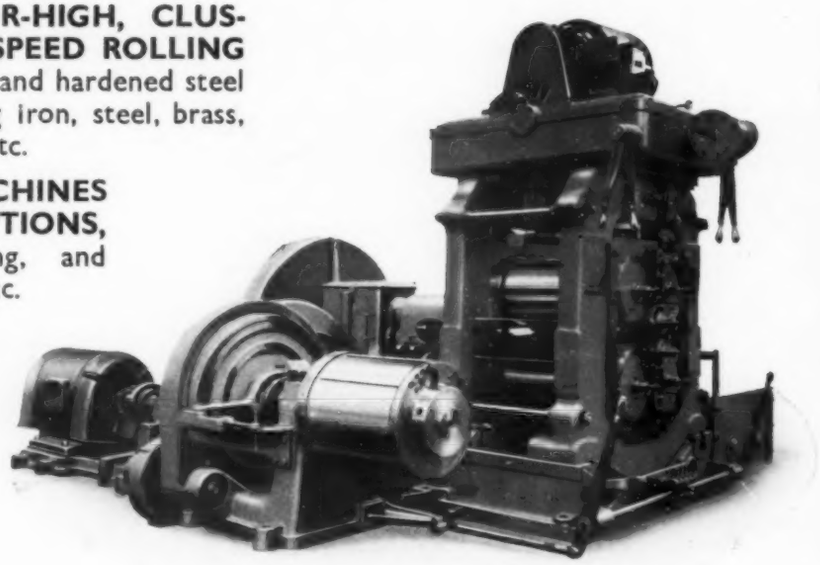

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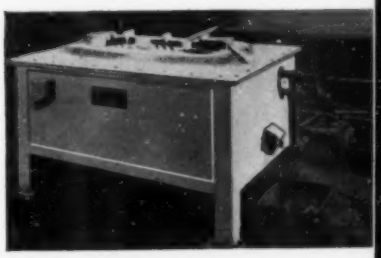

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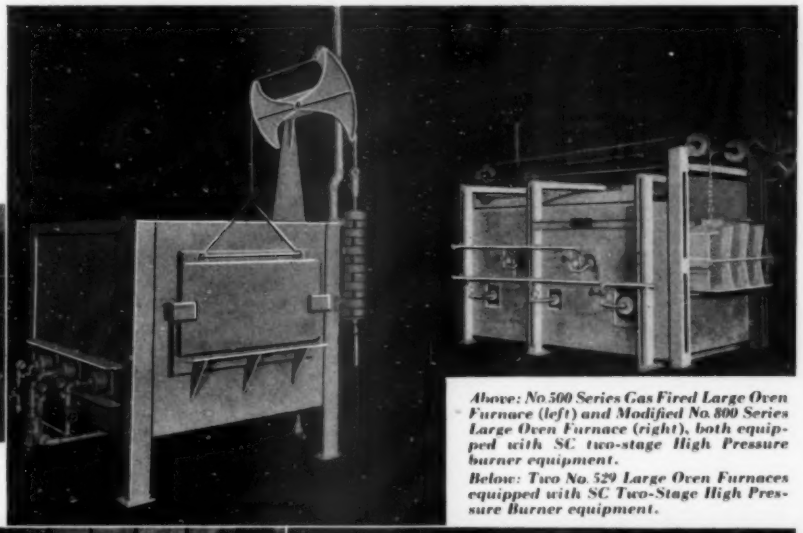

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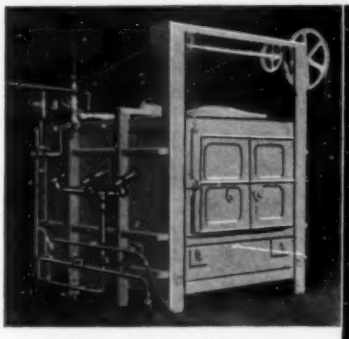

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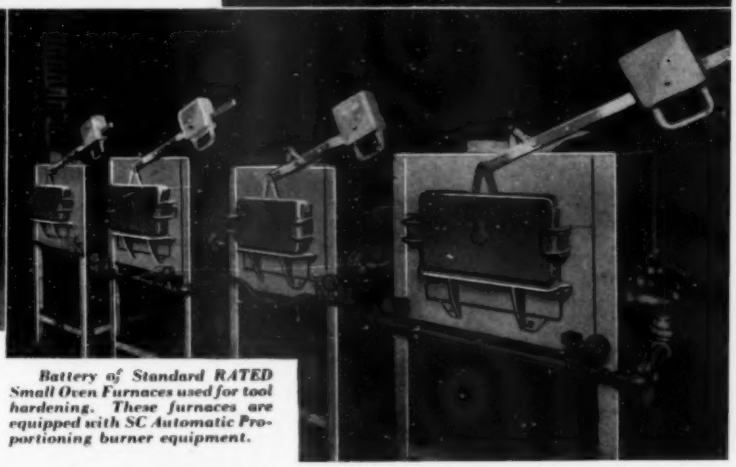

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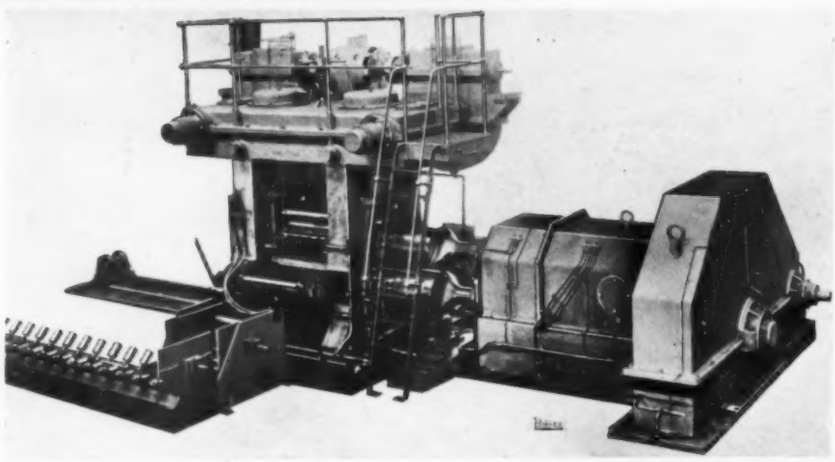

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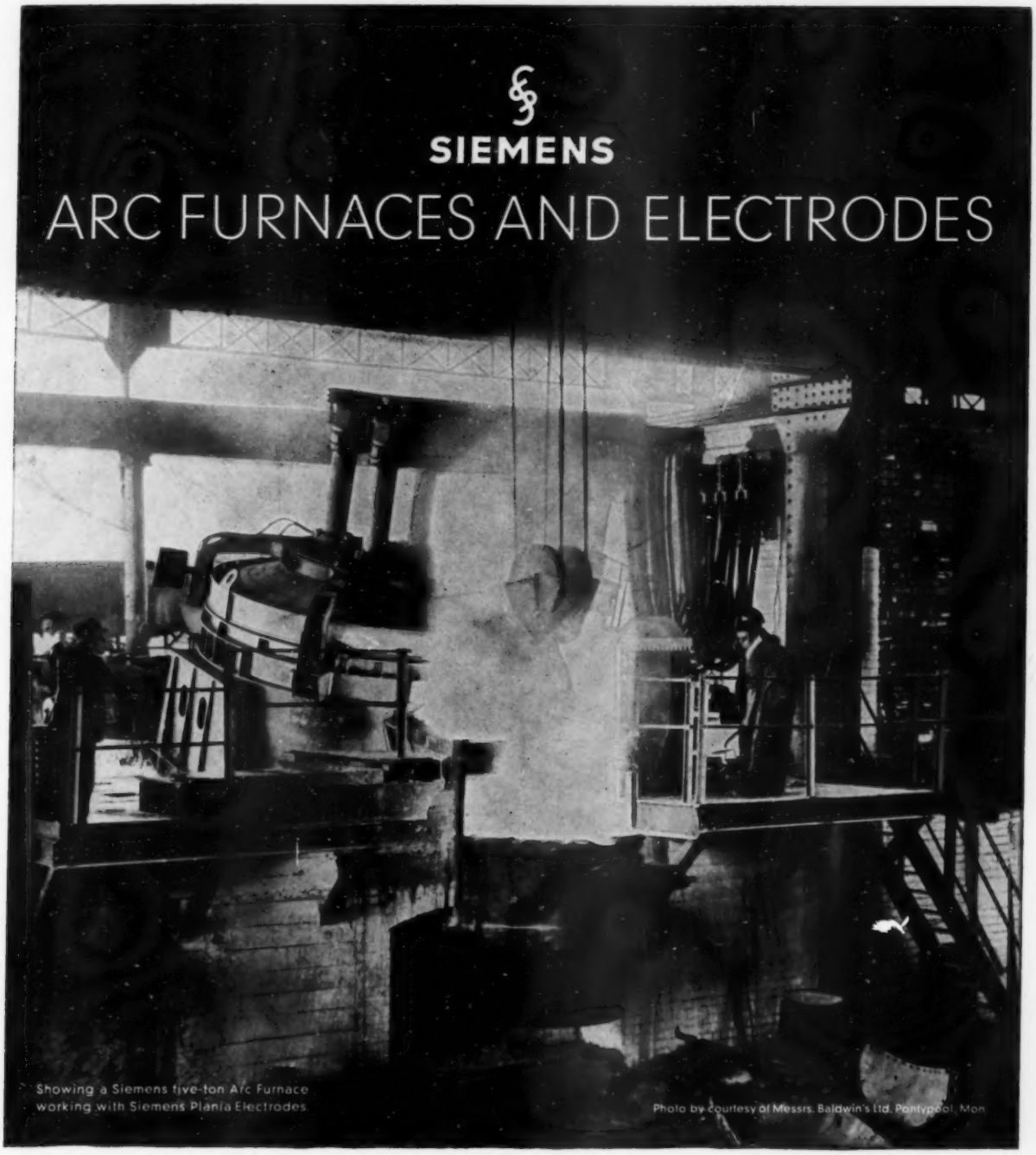
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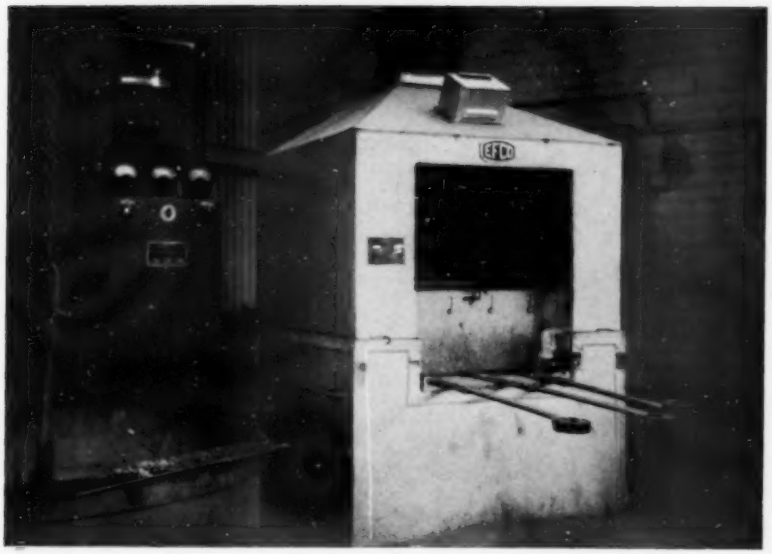

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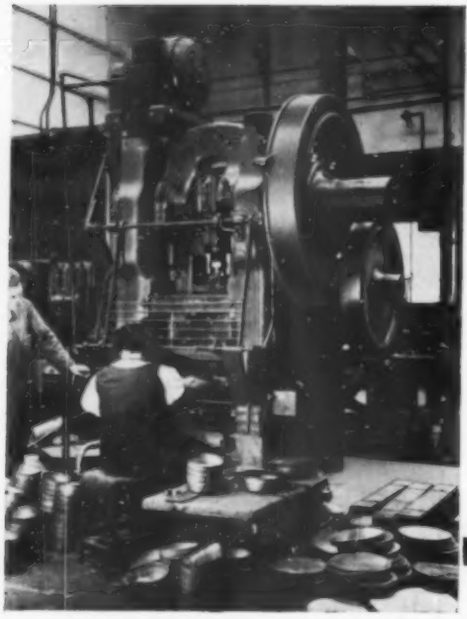

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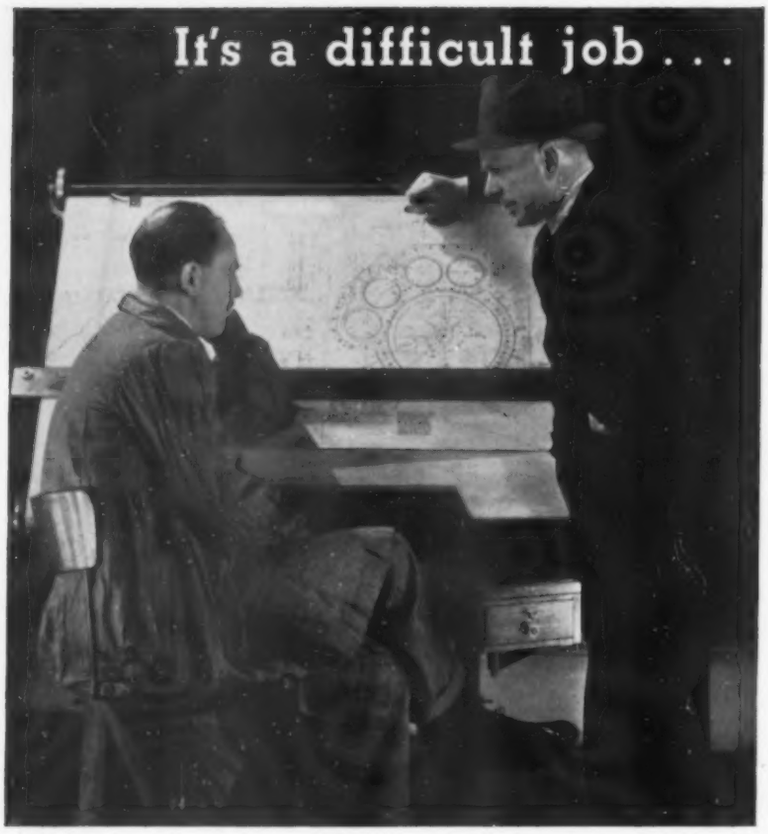

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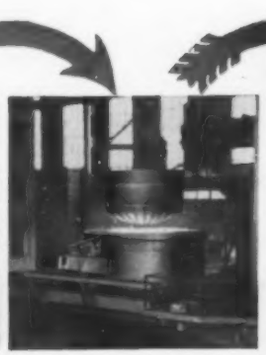

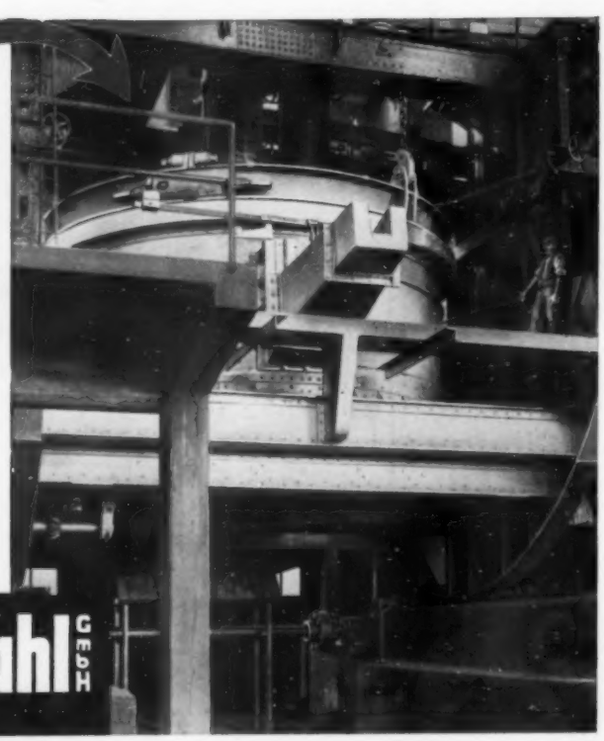

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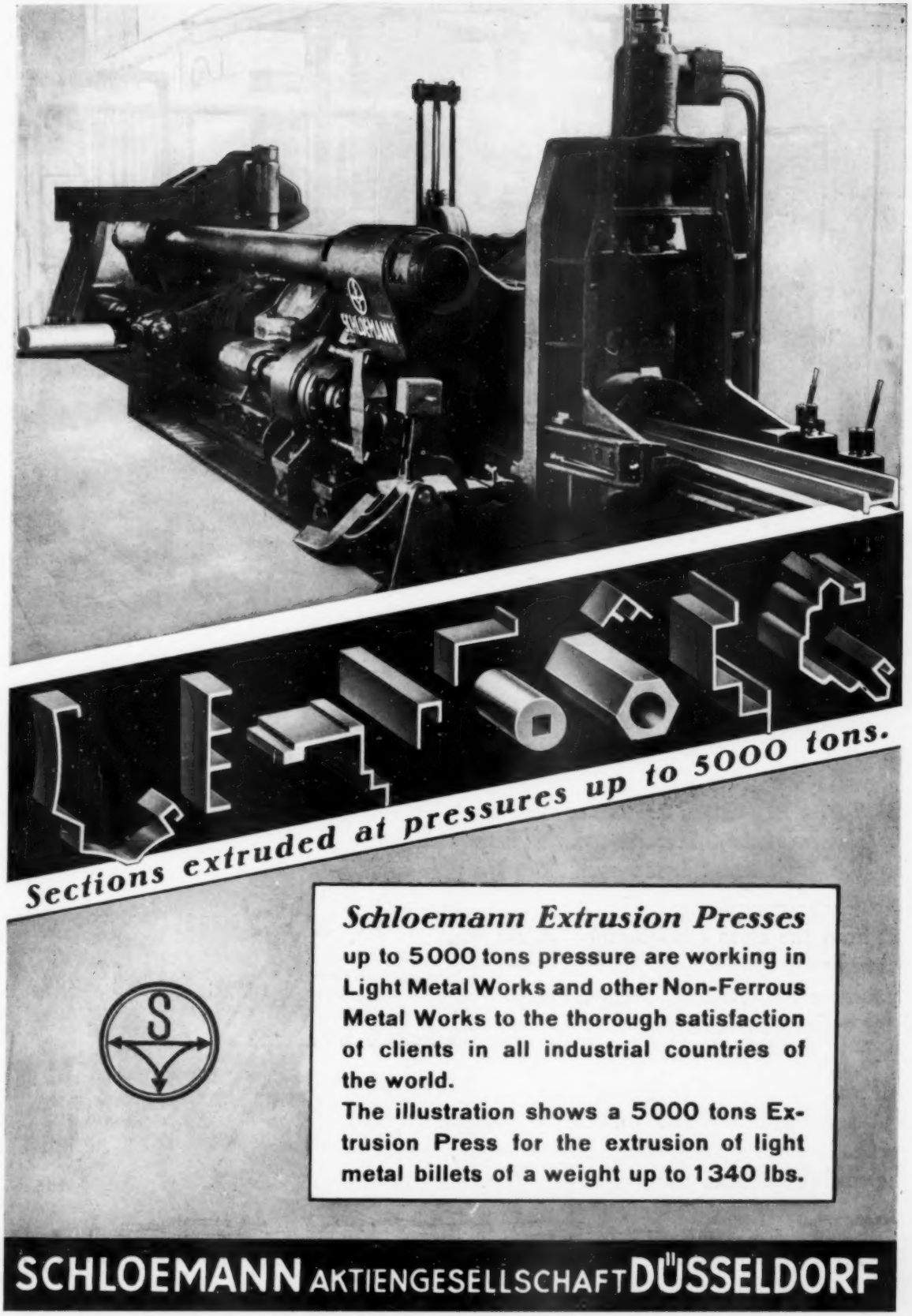

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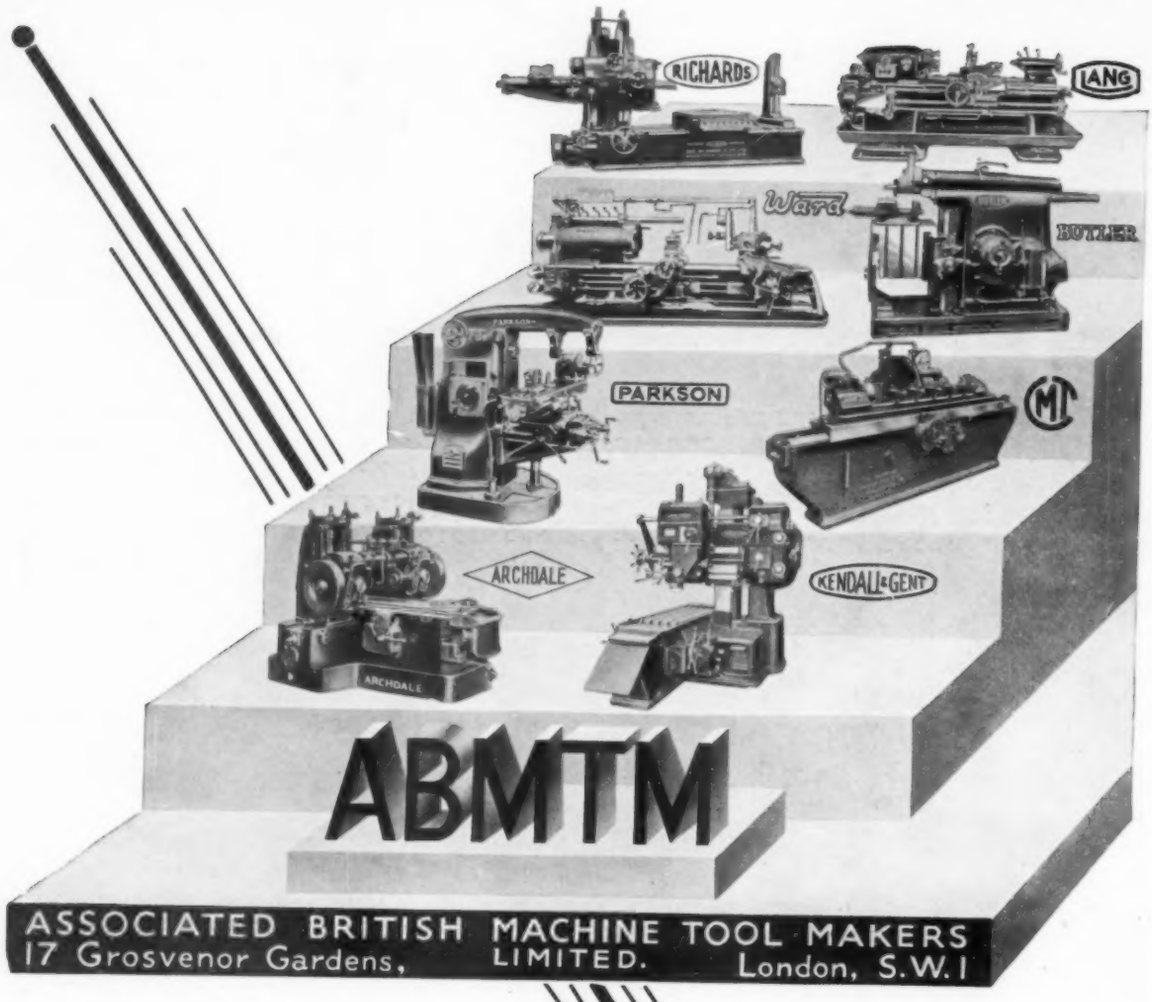

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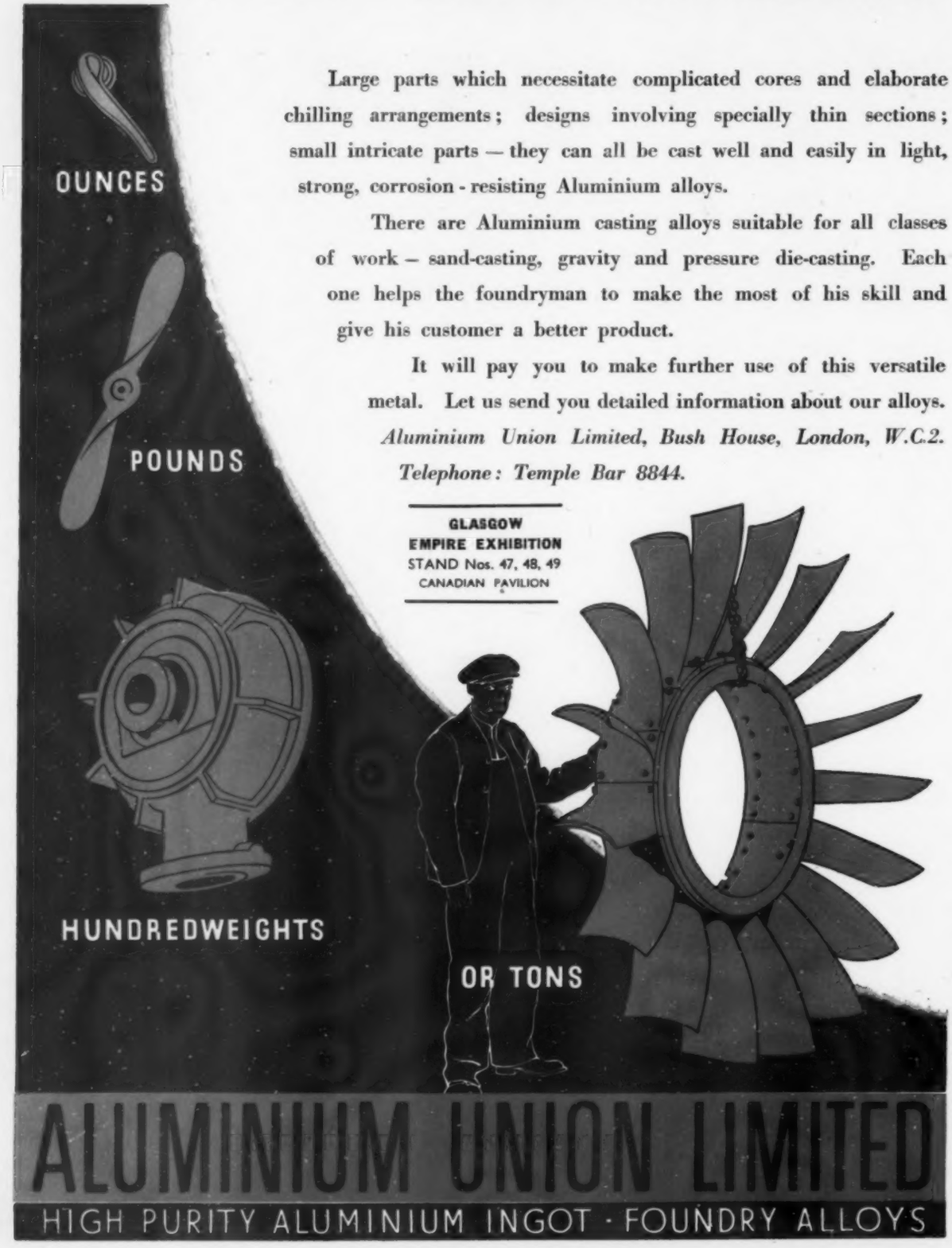

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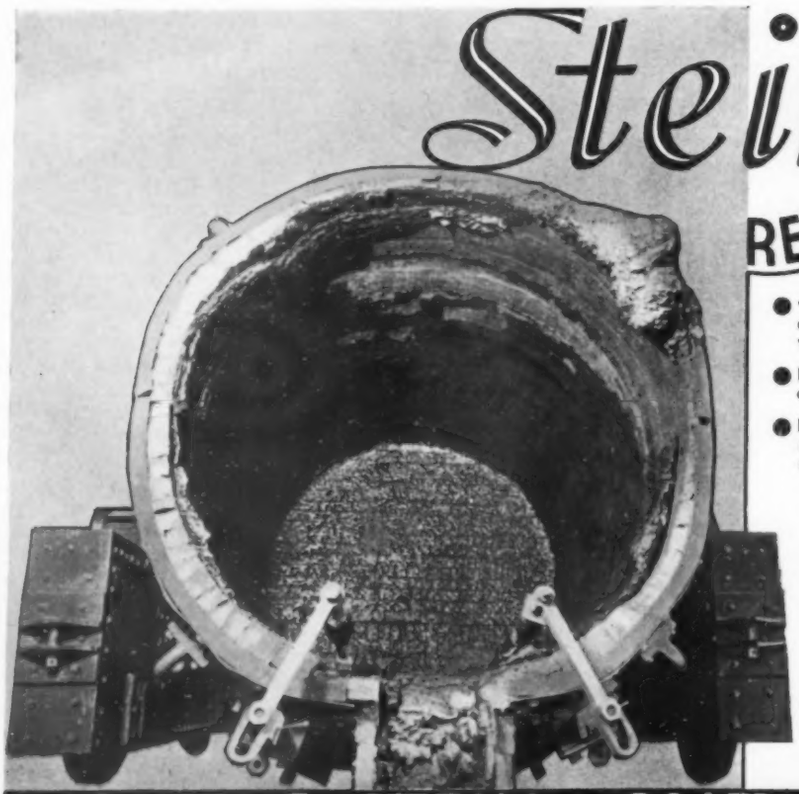

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ROLLING MILL DESIGN AND CONSTRUCTION

AN 8-in. DOUBLE DUO MILL

A modern example of double duo mill is described which combines many features developed for the economical production of miscellaneous steel sections of great accuracy and uniformity of dimensions and designed for long life under modern service conditions.

ALTHOUGH fundamentally the principles involved in the design and construction of rolling mills have not altered since the first mill was designed, there has been great progress in the design of mills for specific duties, and so many refinements have been developed that mills are now regarded as precision tools. With the demand for an increasing range of metals and alloys possessing special properties advances have been made in the design and construction of rolling mills to produce these metals and alloys in the many forms desired, and considerable attention has been given to the accuracy and uniformity of dimensions now demanded of the rolled product.

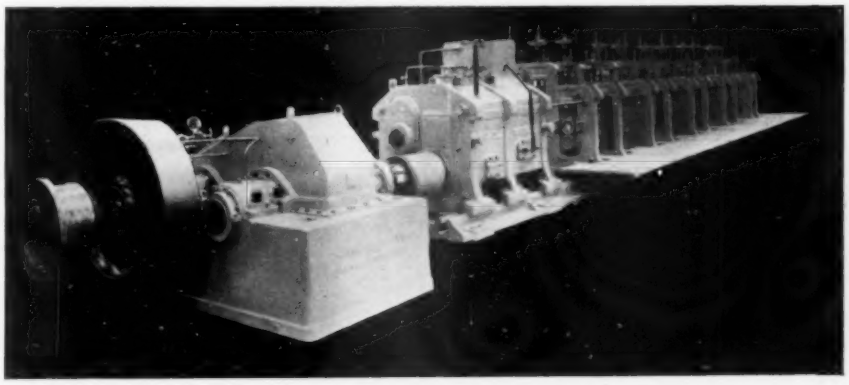


Fig. 1.—The gear unit and the combined diagonal gear and pinion housing unit showing the flexible coupling.

The range of mills is now very considerable, but the underlying principle of all roll pass design is uniformity of drafts on all parts of the pass, thus ensuring all parts of a bar being rolled a consistent forward elongation in the direction of rolling. It is important to maintain a good finish on the rolled section, and in hot-rolling steel sections the temperature of the steel at the final pass is of great importance. While such matters as rolling temperatures, drafts and passes, lubrication of the metal being rolled and the cooling of the rolls, etc., are incorporated in the technique of rolling, the practice employed is inextricably woven with the machinery employed, and it is interesting to describe a mill designed and built by the Brightside Foundry and Engineering Co., Ltd. This is an 8-in. double duo mill, comprising five stands of roll housings, all carried on a continuous bedplate and two stands of change roll housings with individual bedplates. The mill is designed for hot rolling 1¾ in. square billets to produce miscellaneous sections in special carbon and alloy steels. The double duo mill has two sets of rolls, the billet being started through the lower pair and passed over an inclined platform to the upper pair of rolls, the intervening platform being adjustable for the return of the rolled billet. This provides diagonal passes which are claimed to give higher reductions per pass. The mill is driven by a 500 h.p.—300/900 r.p.m. variable speed d.c. motor, coupled to the pinion of a gear set through a Wellman Bibby Flexible Coupling.

The gear unit, which has 36-in. working centres, embodies two steel disc type flywheels; the forged steel pinion and

Fig. 2.—The mill train showing the five stands of roll housings.

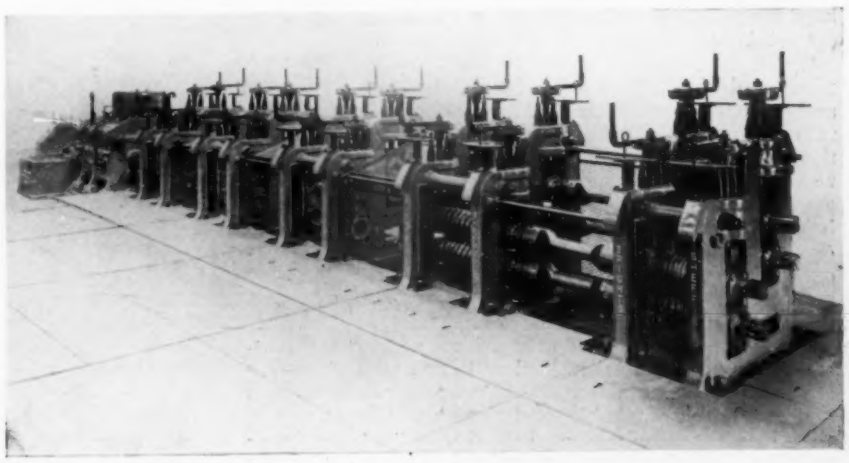


Fig. 3.—One of the change roll housings with coupling spindles and other details in the foreground.

cast-steel wheel having continuous machine-cut double helical teeth, and a main driving shaft of forged steel. The gear ratio is 2 to 1, which gives mill speeds of 150/450 r.p.m. Phosphor bronze bearings are used, carried in a box section cast-iron bedframe, and it is noteworthy that the gear cover is a welded steel structure with detachable cast-iron bearing caps. The bearings and gear teeth are pressure oil lubricated by a motor-driven pump, the system incorporating pressure gauge, flow indicators, cooler and strainer.

The drive from the gear unit to the roll housings, shown in Fig. 1, is through a combined diagonal gear and pinion housing unit. It is transmitted to the pinions through an Ortmann type coupling, comprising two cast-steel ends and a driving sleeve, machined, splines with radial driving faces being formed on the peripheries of the ends and in the bore of the sleeve. The drive is taken by the pinion shaft of the lower set of rolls and transmitted to the pinion shaft of the upper set of rolls through a pair of cast-steel gears having straight machine-cut teeth which are keyed to extended shafts formed on the lower pinions.

The mill pinions are of forged steel, with continuous machine double helical teeth, having the necks polished and revolving in white-metal-lined cast iron chocks located in cast-iron pinion housings by internal and external flanges, and clamped in place by a cast-iron cap anchored to the housing by six cotter bolts. The pinion and teeth are lubricated on the gravity feed principle, the lubricant being fed into the supply tank formed in the pinion-housing cap, and gravitating to the teeth and necks through external pipes having flow indicators and adjustable needle valves, the oil being circulated from a tank by a gearing pump driven by an individual motor.

The roll housings, shown in Fig. 2, are of alloy cast iron, and the windows are machined and lined with renewable steel plates, whilst the cramp-bar slots are also machined and fitted with renewable steel channels. The chocks in these housings are of cast steel fitted with "Fischer" self-aligning roller bearings, longitudinal adjustment of the

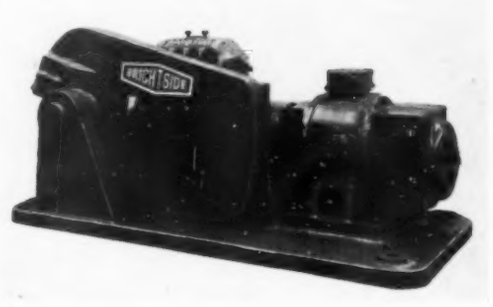


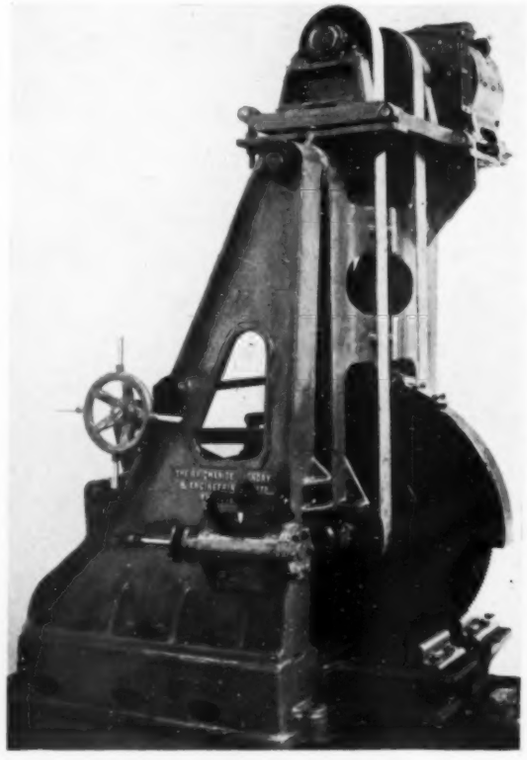
Fig. 4.—Set of crocodile shears.

rolls and chocks being obtained by adjusting bolts and nuts engaging with horns formed on the chocks. The use of roller bearings is one of the refinements which substantially increase the output of a mill; they effect a saving in electric current for the same output, in comparison with a similar mill equipped with ordinary bearings, but as far as this saving is concerned, it is more than counterbalanced by the higher first costs, the cost of roll-changing, of lubrication, and of the rolls themselves. The economical advantage of roll bearings results from the greater output which effects a reduction in production costs.

The top rolls and chocks of this mill are spring balanced from the top of the housings and adjusted vertically by screws working in steel boxes and operated by swivel levers engaging with notched plates located at the top of the housing screws. These screws are located in position by locking pins engaging with holes formed in the quadrant brackets carried off the top face of the housings. The mill coupling spindles are all of "Universal" design, comprising cast-steel "muffs" machined in the bore to a sliding fit on the roll tenors and bored transversely to accommodate the bearing pads and retaining pins.

The coupling spindles are fitted with semi-circular

Fig. 5.—A 36-in. diameter hot saw supplied with the plant.



backed phosphor bronze bearing pads, which have phosphor bronze swivel blocks located between the flat driving faces to engage with the slots in the palm ends. Each set of working parts is fixed in position by means of a high-carbon steel pin. Lubrication is by grease under pressure from a grease gun.

The equipment associated with this mill includes a set of shears of " Crocodile " design, a 36-in. diameter hot saw, and a hot reeling machine. The shears, Fig. 4, are located on each side of the train. Each set is direct coupled to the driving motor through a combined flywheel and pin-type flexible coupling. The hot saw, Fig. 5, is driven by a 1,500 r.p.m. 25 h.p. motor through a flexible coupling to the saw spindle through belts. The hot reeling machine is designed for bars ¼ in. to 1½ in. diameter, it is driven by a 585 r.p.m. 40 h.p. motor through V-belt and machine-cut spur gears. Reeler rolls of chilled cast iron revolving in phosphor bronze bushed chocks, rolls are adjusted by a handwheel through mitre- and worm-gears, and individual adjustment to any one chock is obtained through a claw clutch. The feed and delivery troughs are of fabricated steel; they are fitted with safety catches to prevent " whip " on the bars.

It will be realised from this brief description of one type of mill recently built that a modern rolling mill, which is sometimes defined as a combination of machinery consisting of one or more sets of rolls between which heated metal is passed under pressure, is really a complicated piece of mechanism. This modern example of a double duo mill incorporates many features which, while maintaining a high standard of service, ensure the economical production of miscellaneous steel sections of great accuracy and uniformity of dimensions.

Causes of Porosity in Electro-deposited Nickel on Steel

IT is now established that the most important factor determining the protective properties of composite coatings of nickel and chromium is the porosity of the nickel undercoating. This conclusion has been reached by investigators in many countries who found that the porosity of nickel coatings on steel afforded a reliable indication of behaviour in atmospheric exposure. It is generally assumed that suspended impurities in the bath increase porosity, and that the presence of surface inclusions or impurities in the basis metal is a cause of porosity, but very little reliable information is available on the primary causes of porosity in electro-deposited coatings. This absence of knowledge of causes of porosity in thin nickel coatings, and means for its protection, imposes a serious limitation on the process of nickel plating.

With the object of determining the causes of porosity in nickel deposits an investigation was undertaken by Hothersall and Hammond, the first report on which was presented at the recent general meeting of the Electrochemical Society at Savannah. In the first part of this report the authors attempt to provide a comprehensive analysis of the possible causes of porosity, while the second part is concerned with the more important results of experimental work so far carried out with electrodeposited nickel.

It is shown that porosity can be due to an unsound condition of the deposit, but in nickel deposits it is usually due to a failure of the deposit to grow completely over the basis metal. The chief causes of this failure are considered to be the presence of non-conducting or poorly conducting areas in the surface of the basis metal (for example, inclusions of scale), the shielding action of gas bubbles or of particles of solid matter derived from the solution or loosened in etching from the basis metal, the failure of the deposit to cover the surfaces of crevices in the basis metal either because of poor throwing power or because of the exclusion of electrolyte by trapped gas. Some coatings may be porous because of the inherent tendency of the deposit to grow only slowly in a lateral direction. This factor is not considered important in nickel deposition.

The authors made a preliminary investigation of the causes of porosity in nickel deposits. Methods of testing porosity were examined. The ferri-cyanide reagent has been shown to attack nickel, and this test is therefore unsuitable for nickel coatings. The hot-water test, originally devised for tin coatings, has been found applicable to nickel coatings.

A method of producing very thin nickel deposits (less than 0·0001 in., or 0·0025 mm. in thickness) in a non-porous condition has been developed. This result demonstrates the possibility of producing thin non-porous nickel deposits. The technique described in the report is of considerable value for the purpose of investigation in providing a reliable and rapid method of determining the importance of various factors in causing porosity. The method consists in using specially prepared electrolytic iron as a basis metal, and in depositing nickel from a carefully filtered solution with platinum anodes enclosed in alundum thimbles.

The most important causes of porosity in nickel deposits prepared in still baths on bright rolled steel have been found to be the presence of suspended matter in the solution (for example, very finely divided particles derived from nickel anodes), the presence of inclusions or other solid matter on the surface of the basis metal, and a rough condition of the surface. Bubbles of gas adhering to the surface, or discharged and reformed continuously, do not appear to be a primary cause of porosity since there was no diminution in porosity when bubble formation was inhibited by the addition of oxidising agents to the solution. The effect of solution *p*H on porosity did not appear to be important under the conditions used.

A further cause of the porosity of nickel coatings formed on polished steel has been found to be the inclusion of grease or polishing composition in crevices over which a thin skin of metal (dissolved away in etching prior to plating) is flowed during polishing. The outstanding problems, of which further investigation is required, would appear to be: Further investigation of the type of surface imperfection in the basis metal which is responsible for porosity; a study of remedial methods by which the effect of surface imperfections in the basis metal may be minimised; a study of methods of polishing and of cleaning prior to plating which would avoid porosity caused by inclusions of polishing compounds; and the determination of the relative importance of different types of solid matter encountered in commercial plating baths, with the object of finding methods of minimising this cause of porosity.

Some Aspects of Tin Research

IN the current issue of *Science Progress*, Mr. C. O. Bannister reviews some of the results of research work on matters in which metallic tin is the most important factor. He deals with recent publications issued by the International Tin Research and Development Council, more particularly those in Series A, Nos. 46-72, and shows how important the results are to industry. These publications have, for the most part, been previously presented to various societies, and constitute convenient reprints which may be obtained free of charge from the Council.

Canadian Copper Production in 1937

CANADA'S supply of copper is obtained from the copper-nickel ores of Sudbury, Ontario; the copper-gold ores of Noranda, and the copper-pyrites ores of Aldermac and Eustis, in Quebec; the copper-zinc ores of Flin Flon and of Sherritt-Gordon in Northern Manitoba; the copper-zinc ores of Britannia and the copper ores of Copper Mountain in British Columbia. Some copper is also recovered as concentrates from the lead-zinc-copper ores of Stirling mine, Cape Breton, N. S.

In British Columbia the Britannia mine and 6,000-ton concentrator at Britannia Beach were operated at full capacity, producing copper and zinc concentrates which are exported. The Granby Consolidated Company resumed operations in the summer of 1937 at its Copper Mountain mine and Allenby 3,000-ton concentrator near Princeton; the copper concentrate produced is being exported. The Flin Flon mine and smelter on the boundary line between Manitoba and Saskatchewan operated at full capacity. The Sherritt-Gordon property was under development throughout the year and milling was resumed in July, the copper concentrate being smelted at Flin Flon.

In Ontario the production from the mines of the Sudbury district exceeded by far that of any previous year. The No. 5 shaft at the Creighton mine was completed down to 4,050 ft. and has facilitated the development of new ore zones and the increasing of the output from this mine. The Garson mine, after being closed for several years, was re-opened in the latter part of 1936 and operated at full capacity in 1937. The Levack mine was reopened early in 1937; the sinking of a new 2,000-ft. shaft was started in the latter part of 1937, and a complete new surface plant is being built. The Copper Cliff concentrator, the capacity of which has been increased in 1936 from 8,000 to 12,500 tons of ore a day, is being further enlarged to permit the treatment of part of the enlarged mine output. The additions to the smelter at Copper Cliff in the form of new reverberatory furnaces and converters completed towards the end of 1936, increased the production capacity of the smelter for blister copper and for nickel matte by one third. The construction of the Research and Chemical Laboratory at Copper Cliff was completed and placed in operation during the latter part of the year.

Falconbridge Nickel Mines, Limited, deepened its No. 1 shaft to 2,126 ft. with bottom level at the 2,100 ft. horizon; No. 5 shaft, which has a depth of 1,800 ft. is connected on the 1,200-ft. level with No. 1 shaft; several hundred feet of development was done on the 1,750-ft. level (bottom level) from No. 5 shaft, and a crosscut started from No.1 shaft at the same horizon. During the year the known ore reserves of the mine were much increased. Additions to the surface plant, including enlargement of the concentrator and the smelter which was started during 1936 and completed early in 1937, increased the capacity of the plant to 12,500 tons of nickel-copper matte, all of which is exported.

In Quebec, Noranda Mines, Limited, operated its mine and smelter at normal rate throughout the year; sinking of No. 5 shaft, started early in 1935, was continued in 1937 to a depth of 4,000 ft. and exploration works started on the 3,475-ft., the 3,725-ft. and 3,975-ft. levels. The Aldermac mine and 1,000-ton mill resumed operations in January, 1937. The Waite-Amulet mine and 350-ton concentrator also resumed operations in 1937. The Eustis mine in southern Quebec continued in regular operation, exporting its copper concentrate to the United States. The Normetal (Abana) mine north of Dupuy station on the Canadian National Railway, started production in 1937, after completing the new 250-ton concentrator; the copper concentrate produced is shipped to Noranda smelter and the zinc concentrate is exported to Belgium.

The refinery of the Ontario Refining Company at Copper Cliff, Ontario, and that of the Canadian Copper Refiners, Limited, at Montreal East, Quebec, were operated at their annual nominal capacities of 120,000 tons and 75,000 tons, respectively; the latter plant, which is being enlarged to the capacity of 80,000 tons, treated the anode copper from Noranda and the blister copper from Flin Flon, and the Copper Cliff plant treated the entire output of blister copper of the International Nickel Company's smelter.

The method of receiving blister copper from the International Nickel Company in molten state, which was tried experimentally in 1936, was perfected during 1937 and four movable holding furnaces mounted on broad gauge railway trucks are now in operation between the smelter and refinery, transporting the blister output of the smelter a distance of two miles to the refinery's anode furnaces. While this method of transportation has been in use in the steel industry for some time, it is the first time it has been applied to large-scale handling of blister copper.

During 1937 Ontario Refining Company brought into commercial production the smelting of copper cathodes in an arc-type electric furnace of 30 tons capacity. This is one of the outstanding developments in the copper refining industry. In addition, this Company put in a machine for double pointing vertically-cast copper wire bars. The improved product has been favourably received by copper rolling mills in Canada and abroad.

The total Canadian production in 1937 was 265,521 tons, valued at $69,049,734, as against 210,014 tons valued at $39,514,101 in 1936; of the total production Ontario contributed 61%, Quebec 18%, Manitoba and Saskatchewan 12%, and British Columbia 8%.

Exports were:	Lb.		$
Copper fine in ore, matte, etc.	73,867,600	..	7,409,381
Copper blister	10,884,300	..	1,333,073
Copper in ingot, bar, rod, etc.	296,141,300	..	38,705,380
Copper, old and scrap	5,551,000	..	549,638
Copper, in rod, strip, sheet, plate, and tubing	51,224,800	..	7,310,329
Copper wire and cable	—	..	436,834
Copper manufactures	—	..	410,647
	—	..	56,155,282

The greater part of Canadian refined copper comes to this country, where the consumption of new copper in 1936 was at the rate of about 250,000 tons annually, as against 160,000 tons in 1928, the year of greatest consumption before the depression. The electrical industry is by far the biggest consumer of copper in Great Britain.

Structural Steel with Superior Properties

THERE is a demand for constructional steels which have properties superior to the ordinary mild steels yet are available at prices suited to industrial and bulk use. Alloy steels do not yet meet the requirements of this field, not only on account of high cost, but because their properties are only developed after heat-treatment. Of these demands the most insistent are for steels which will offer increased resistance to corrosion and those possessing superior strength, such as will permit the design of parts of structures of lighter weight than is possible with the normal type of mild steel.

Among a number of steels which are manufactured to meet these demands are "Kuplus" weather-resisting mild steel, and "Kuplus" high-tensile steel. The former is not rustless, but it is considerably more resistant to atmospheric corrosion than is ordinary mild steel, and it offers a valuable aid to the designer of structures exposed to the effects of damp or fume-laden air, certain dilute acids and sulphurous gases, and as a substitute for wrought iron, but with superior strength. The "Kuplus" high-tensile steel has the same corrosion-resisting capacity as the weather-resisting type, but it has a permissible unit-working stress of approximately 50% more than normal structural mild steel. Complete data regarding these steels are given in a booklet recently issued by Appleby-Frodingham Steel Co., Ltd., Scunthorpe, Lincolnshire.

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

The Conservation of Metals

METALS have been used since early times, but it was not until the industrial revolution in Great Britain that the mechanisation of industries led to any considerable development of mineral resources, first slowly and with a limited range of products, then, as the revolution spread to other countries, with greatly accelerated momentum, on a large scale and with an extended variety of products. So great was the development in the use of metals towards the end of the last century that dire predictions were made as to the evil consequences of too rapid exhaustion of mineral deposits. These early alarmists failed to envisage the remarkable contributions that were to be made by technology. Associated with the developments in the use of metals, without which progress would have been impossible, are numerous scientific discoveries, inventions, technical and transport developments, and the discovery of ore bodies. To-day, we are well aware of these achievements, and can foresee still further contributions by geology, engineering and metallurgy in extending the useful life of mineral resources.

Gradually, however, with the ever-expanding metal requirements, the need for the conservation of metals has become very real, and common sense, as well as economic necessity, has indicated more prudent use of the ores available, without waste or needless destruction. It has been realised that since metals are indestructible to a large degree, the process of mining, smelting, and refining merely results in a transfer of metal resources from the depths of the earth to the surface, and that the stock of metal in use is no less a valuable resource than unmined ore.

A study of modern industrial conditions shows how much the material prosperity of a nation is dependent upon its trade in minerals, and it also shows that even the richest of nations in material endowment is not self-contained in its mineral needs. As a matter of fact, despite the tendency towards self-sufficiency, there are no national boundaries in the distribution of mineral supplies; some kinds are so widely distributed that nearly all industrial countries have adequate supplies within their own boundaries; other minerals, on the other hand, are so distributed that a surplus exists in some parts with a deficiency in others. Broadly speaking, therefore, conservation may be regarded as the efficient use of the world's resources, which does not mean withholding national resources from use, but the economical development of the resources to the advantage of the country in which the ores are available, remembering that they are held in trust for the benefit of mankind generally. But it is frequently assumed that conservation is concerned only with the production phases of the metal industries, whereas the effective conservation in the utilisation phases are, at least, as important.

Except for a few metals, such as zinc and tin, only a relatively small part of the metals used can never be reclaimed. Obviously, therefore, real conservation can be achieved by promoting the constant use and re-use of that part of production which is not destroyed in service. Thus, the recovery of scrap and wastes, and their use with or instead of metals produced from ores, is sound economics, and entirely in accordance with the general principle of conserving natural resources. Much has been said for and against the use of scrap metal and of primary metal, and there is no doubt that when producers concerned in the recovery of metal from scrap and wastes, first commenced operations, there was ample reason for criticism, but at that time they had no adequate technical control of operations, whereas to-day technical advancement has facilitated the production of reliable secondary metals, and the progress made in their use is contributing in conserving precious supplies of the world's metals.

Another aspect of this subject is raised by Mr. Barclay, in his Calvin W. Rice lecture to the American Society of Mechanical Engineers, in which he stresses the need for co-operation between the engineer and the metallurgist in devising the most efficient and economical use of the raw and semi-finished materials. We live to-day in a period in which we are trying paradoxically to combine high standards of living with super-extravagant expenditure in armaments, which essentially mean waste. All nations apparently are anxious for peace, but have been unable, as yet, to devise ways and means whereby this can be attained and extravagance brought to an end, but the desire of mankind for a high and still higher standard of life is instinctive, and will not be denied. Ultimately, this can be attained only by a strict observance of the laws of economics.

Many countries have been, in the past, and still are, very extravagant in their use of raw materials, and it is doubtful whether they can afford to be so much longer. The availability of at least some metals is definitely limited as far as our present knowledge or the earth's resources extends, but even if ample supplies of all metals were known to be available for many centuries to come, that is no justification for waste. Mr. Barclay considers that the laws of economics are to-day lightly held, but like other laws, if not obeyed, the penalties for disobedience must sooner or later be paid in full. The metallurgist is giving to the engineer, almost day by day, new and improved materials capable of bearing greater strain, giving longer life and resisting more and more successfully the ravages of corrosion. This fact in itself opens out great possibilities in the future for the economical use of nature's provisions for man. It will be appreciated, however, that the industrial development of new or improved metallic alloys depends, almost entirely, on the engineer for their ultimate usefulness in the service of man. Not one of these alloys can be of real use to mankind until it has been made so by the engineer; the one important factor in the conservation of metals is the closest possible co-operation between the metallurgist and the engineer.

True conservation of metals, therefore, is not only concerned with the prudent use of the natural resources, but also with the constant use and re-use of that part of production which is not dissipated in service and the efficient use of combinations of metals in the form of alloys, which give longer service and resist more successfully the effects of time and service. Just as it is an economic sin to use primary metals when less expensive secondary metals or scrap will serve equally well, it should be a sin to disregard the discoveries and developments of the metallurgist in providing new and improved metallic alloys, which possess greatly increased strength, give longer service and resist more successfully the dissipative effects of atmosphere, chemical contact, high temperatures, etc., than the materials in more general use to-day. It is this latter aspect of conservation which offers scope for the less extravagant use of raw materials.

Deutsche Gesellschaft Für Metallkunde

The Recent Annual Meeting at Munich

THE twenty-second annual meeting of the Deutsche Gesellschaft für Metallkunde (the German equivalent of our Institute of Metals) was held this year in Munich, under the presidency of Dr. Rohn, of vacuum-melting fame. It was attended by some 450 members out of a total membership of less than 700, and by some 50 "guests," and practically the whole of these 500 metallurgists attended all the technical sessions, which lasted the whole of two days: from 9 till 1 and from 3 till 6. There were no visits to works or other counter attractions, though specially conducted visits to the famous Deutsches Museum, and to various technical institutes on the day prior to the technical sessions were arranged.

On the first evening a "Begrüssungsabend" in Bavarian style was arranged at the big restaurant on Lake Starnberg, about 15 miles from Munich, and members were taken there and back in motor coaches, and on the second evening there was a dinner in the Bayerischer Hof Hotel. Needless to say, the organisation was perfect, and everything done with true German thoroughness and punctuality—in fact, we always seemed to be just a few minutes ahead of time.

The guest of honour was our own Professor Desch, of the Metallurgical Department of the National Physical Laboratory, who read a paper (in German) on "Superpurity Metals," and was made honorary member of the Gesellschaft, an honour which he shares with Professor Thaman. On the day after the meeting, Sunday, a whole-day trip to Kufstein in Austria was arranged, and anyone remaining over Monday could again visit technical institutes, etc.

The papers were divided into two main sessions, those on the first day dealing with "Werkstoffprüfung" or testing methods, and those on the second day with scientific research. The business meeting took place at 8-30 a.m., before the technical session on the second day, and was followed by a presentation to Dr. Desch, who opened the session with his paper.

All papers were read in full, or as near full as the time allocated to each author allowed, short summaries only being available in printed form and handed to members with their other papers at the Reception Office. This system does not conduce to intelligent discussion, for which study of the paper at leisure and preparation of notes is essential; discussion was therefore conspicuous by its absence, and largely confined to questions and appreciative remarks by the president. Among the matters dealt with at the business meeting was a plan for amalgamation with the Gesellschaft Deutscher Metallhütten und Bergleute, following the example set by the Institute of Metals and the Iron and Steel Institute.

What struck us perhaps most about this meeting was its essentially "German" character. Dr. Desch and the writer were the only representatives from non-German-speaking countries in the official list, and we met no other foreigners (other than a few Swiss), and we heard nothing but German spoken. In conversation with leading members, admiration for the large foreign membership of the Institute of Metals was frequently expressed, and a keen desire shown for closer co-operation with our Institute, a matter which was the subject of discussions between Dr. Rohn and Dr. Desch, the results of which will be known in due course.

Another noticeable feature was the high percentage of young men attending the meeting, special arrangements for their accommodation in the smaller hotels, boarding houses, and even private houses having been made by the Gesellschaft. Members wishing to avail themselves of this filled in a form sent out with the programme of the meeting, indicating in which of three price grades they desired accommodation, and the Gesellschaft did the rest. The address was given on the ticket included with the papers at the Reception Office, which was installed at the railway station, and was open from 8 a.m. the day before the meeting. We arrived at 8-2 and were not the first, though nearly so. Hats off to Herr Groeck, the Geschäftsleiter or secretary,

And last, but by no means least, was the practical absence of the industrial and commercial element. At least 90% of those attending the meeting were research workers, either from industries or laboratories, whilst the social element was also lacking, due perhaps to the very few ladies who accompanied their men-folk. It was obvious that the main attraction to all attending the meeting was the opportunity to meet their opposite members in other firms or laboratories and compare notes. Germany is a big country, with many widely scattered centres of knowledge and industry, whilst travelling is a luxury which few can afford, so that workers have little opportunity of interchanging ideas except at these annual functions—hence the stupendous attendance level, about 65% of the total membership.

Among the more interesting papers, which numbered 27, were:—"The Production of Super-purity Metals," by Dr. Desch; "The Laws of Linear Crystal Growth," by Dr. Masing; "Magnetic Tests in Non-ferrous Research," by Dr. Auer; "Overlapping of Different Hardening Processes," by Dr. Dannöhl; "Researches into Aluminium Bearing Metals," by Dr. von Schwarz; "Endurance Limit of Wrought Aluminium Alloys," by Dr. von Rajakovice; "Measurement of Hot Strength Below and Above Recrystallisation Temperature," by Dr. Rohn; "Measurement of Stress Corrosion," by Dr. Brenner; and "Testings of Aluminium Castings," by G. Gürtler.

The Production of Pure Metals

The influence of very small percentages on the properties of metals has caused considerable research work with a view to the production of pure metals. The importance of pure metals was emphasised in the paper read by Dr. C. H. Desch, who said that in recent years considerable attention had been given to their production in view of the need for the purest available metals for research on equilibrium diagrams and for the determination of the physical and mechanical properties of the metal as well as of the effect on them of added elements.

Even in the purest metals so far obtained the number of foreign atoms per unit volume is still very considerable. The effects of these small amounts of impurities are enhanced by the tendency, in the case of soluble surface-tension-lowering elements, to become concentrated at the boundaries of the grains of the basis metal. A similar concentration of the boundaries of mosaic structures probably accounts for the effects of impurities on the electrical and magnetic properties. This tendency to concentrate at boundary surfaces explains the very large relative effects of small amounts of a dissolved foreign element as compared with the effects of further larger additions of the same element. The reverse holds good on progressively removing the impurities.

The effect of removing small amounts of impurities is especially marked in the case of aluminium. This element, with a purity in excess of 99·99%, exhibits the phenomenon of self-annealing. The softness of the metal also makes the breaking of the structure and lattice distortion much more difficult in the case of aluminium-copper alloys prepared from super-purity aluminium.

In the case of metals such as aluminium, lead, zinc, cadmium, copper and magnesium, refining on a laboratory scale is difficult, and it is preferable to make use of commercially produced pure metals which are of a satisfactory degree of purity. On the other hand, special small-scale methods have been developed at the National Physical Laboratory for the production of pure iron, chromium, manganese, silicon, nickel and cobalt. Dr. Desch dealt with these methods in some detail and described some of the apparatus used in the research on pure metals and alloys.

Long-term Growth of World Aluminium Output

By Robert J. Anderson, D.Sc.

Comparisons are made in the output of aluminium with that of other important non-ferrous metals ; outputs are plotted over a long period on the basis of cubic volume, which gives a better comparison when light and heavy metals are considered. Reference is made to factors which have contributed to the rapid growth of the aluminium industry, and the outlook for its expansion is discussed.

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THE rapid growth of the aluminium industry, especially after the World War, represents one of the most remarkable and interesting developments in the history of metal economics. Only about fifty years have elapsed since aluminium was first produced on a small scale by the Hall-Héroult electrolytic process. Thus, the present position of the modern industry has been attained in a relatively short time. Aluminium now ranks among the major base metals. In respect of world output by weight it stands fifth, following iron, copper, zinc and lead ; and with regard to monetary value of the output it stands fifth, after iron, copper, tin and zinc. With reference to volume of output aluminium ranks fourth, following iron, copper and zinc. These orders are based on the preliminary statistics for 1937.

Continual progress in improving the economic utility of aluminium has been the predominant factor in the marked advance of the world industry over the long term. Some special circumstances—including the autarchic movement and the rise of nationalism—have also been influential, particularly during recent years. The field of application for aluminium has been constantly expanding as a result of its increasing usefulness, which has been convincingly demonstrated as time has passed. Aluminium is commonly employed, and preferred to-day for numerous purposes, in place of other metals on account of its inherent properties. These are of exceptional worth in many applications. Furthermore, aluminium has supplanted various materials, both metals and other substances, because it either costs less or is more suitable, or both. Light aluminium alloys are, of course, comprehended in referring to properties and general uses.

A number of outstanding technical achievements have contributed to the enhanced utility of aluminium and, consequently, expansion of the industry. Important work has been done during the last 15 years in connection with metal of high purity, alloys, heat-treatment, equipment for the production of wrought manufactures, large shapes, methods of fabricating, welding, structural design, foil, powder and surface finishes. As the result of technological progress in these and other directions many new products have been developed, and the market for aluminium has been greatly broadened. Thus, the use of aluminium has been extended to purposes for which it was formerly uneconomic in competition with other metals and materials. It is worth special note that the cost of producing aluminium has been appreciably decreased over a period of late years. Accordingly, producers have been enabled to reduce the selling price. Since 1926 the trend of prices for primary aluminium, semi-manufactures and finished goods has been downward.

Both world output of aluminium and the number of producing countries have increased substantially in the last decade. In 1920 the total number of aluminium-producing countries was nine, and world output was about 128,000 metric tons. In 1928 there were 10 producing countries, and output was about 256,000 metric tons. In 1937 aluminium was produced in 15 countries, and world output was about 504,000 metric tons. At present, capacity for aluminium reduction is being enlarged in various countries, and plans have been projected for building works in other countries where the metal has hitherto not been produced. The indications are that the total number of producing countries may exceed 20, and that world capacity may be increased by about 30% within a few years.

In appraising the current and prospective economic position of the aluminium industry it is requisite to examine the growth of world output over a long period. Besides, it is necessary to compare the output of aluminium with that of the other important non-ferrous base metals.

Weight of Outputs

The electrolytic production of primary aluminium on an industrial scale was begun in the United States and Switzerland shortly before 1890. Within 20 years the annual world output had been raised to fairly substantial amounts. Quantitative growth of output was rather slow until about 1900. Demand for aluminium increased considerably in the following decade with the advance of the automobile industry, but output still remained far below that of copper, lead and zinc. The gap between tin was, however, being gradually narrowed. World output of aluminium exceeded that of tin for the first time in 1910 on the basis of volume, and in 1917 on the basis of weight.

Aluminium output was increased greatly during the years of the World War, under the impetus of demands for military purposes. Since 1921 the trend has been sharply upward, interrupted by the severe industrial depression of 1930–1933. World output of the several non-ferrous metals in 1929 was the highest reached theretofore. In this connection it is of interest to note the comparative outputs of the metals in that year and in 1937. Output of aluminium was nearly 79% greater in 1937 than in 1929. The relative outputs for some other metals in the same years were approximately as follows: Copper, +24% ; lead, −14% ; tin, +8% ; and zinc, +15%. (The preliminary figures of outputs for 1937 may subsequently be corrected to the extent of ¼% to 1%). These percentages make evident the rapidity with which the aluminium industry has been expanding during late years in relation to the other metal industries.

In order to see readily the situation with regard to development in world outputs of the competitive non-ferrous metals during the last half-century the graphs of Figs. 1 and 2 may be noted. Reliable statistics as to the annual output of magnesium are not to be obtained, and this metal is therefore excluded from consideration here. World output of magnesium in 1937 is estimated at 25,000 metric tons, or about 5% of the aluminium output.

Fig. 1 is a chart which shows the annual world outputs by weight of primary aluminium, copper, lead, tin and zinc over the period 1890–1937. On the basis of weight the world output of aluminium is currently still much less than that of copper, lead and zinc, but substantially greater than that of tin. The graphs of Figs. 1 and 2 exhibit clearly the effects of the World War, the business boom

ending in 1929, and the first and second post-war depressions on outputs of the metals. They also indicate the relative elasticity of demand for primary metals as influenced by trade cycles.

In examining the present economic position of aluminium, it is interesting to consider the comparative rates of increase in world outputs of the several metals over a reasonably long time. The average annual rate of increase in output is a good criterion of the trend. Taking account of the increments and decrements from year to year, the average annual rate of increase in world output of aluminium for the period 1900–1937 was about 14·7%. The average annual rates of increase in world outputs of the several other metals for the same period were approximately as follows: Copper, 6%; lead, 1·9%; tin, 2·3%; and zinc, 4·5%.

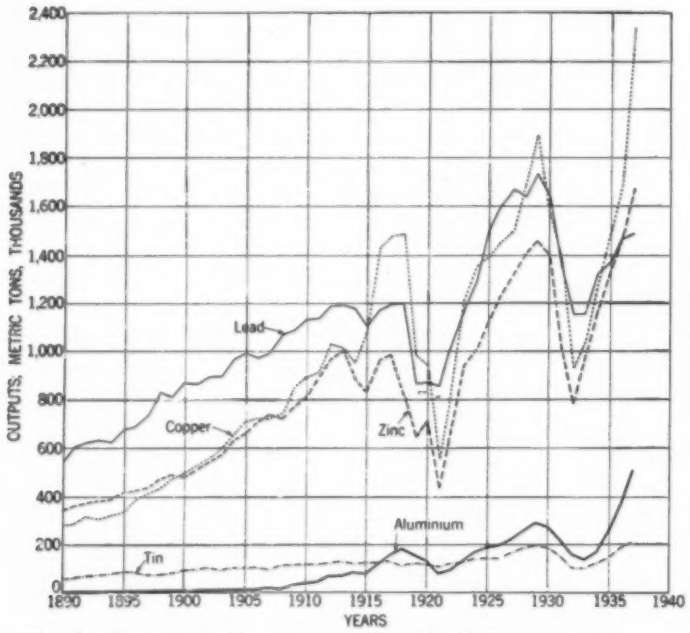


Fig. 1.—Annual world outputs of the principal non-ferrous metals, 1890-1937; weight basis.

Comparison may also be made of world outputs for an early period with one 25 years later, in order to show the relative growth of the metal industries. Thus, world output of aluminium for the five-year period, 1933–1937, was about 480% greater than for the period 1909–1913. The corresponding approximate increases for the other metals were: Copper, 67%; lead, 19%; tin, 28%; and zinc, 49%.

Table I gives the metal outputs *per capita* of world population in 1900 and 1937. As in the case of the comparisons made above, the increase of aluminium is especially notable.

For 1937 the rank of countries as to output of primary aluminium was as follows: United States (first), Germany, Soviet Union, Canada, France, Switzerland, Italy, Norway, United Kingdom, Japan, Austria, Sweden, Hungary and Jugoslavia.

Volume of Outputs

The direct comparison of outputs on the basis of weight is misleading to a degree depending upon the differences in density of the metals. This is also true with respect to the comparison of selling prices. For the present purpose it is more apposite to consider the metal outputs on the basis of volume rather than of weight.

Following are the approximate densities of the several metals under consideration here: Aluminium, 2·7; copper, 8·9; lead, 11·4; tin, 7·3; and zinc, 7·1. Accordingly, a given volume of aluminium weighs about 24% as much as the same volume of lead, 30% of copper, 37% of tin, and 38% of zinc. Or, expressed in another way, a given weight of aluminium occupies about 4·2 times as much space as the same weight of lead, 3·3 times of copper, 2·7 times of tin, and 2·6 times of zinc. Hence, the representation of outputs by volume, instead of by weight, serves to convey a more correct idea of the quantities produced, especially in comparing light and heavy metals. This is illustrated nicely by the relative positions of the graphs in Fig. 2 as contrasted with those in Fig. 1.

TABLE I.

OUTPUTS OF NON-FERROUS METALS PER CAPITA OF WORLD POPULATION IN GRAMMES.

Year.	Aluminium.	Copper.	Lead.	Tin.	Zinc.
1900	4·7	319·1	562·1	61·2	308·7
1937	252·2	1,172·8	741·6	105·4	838·3

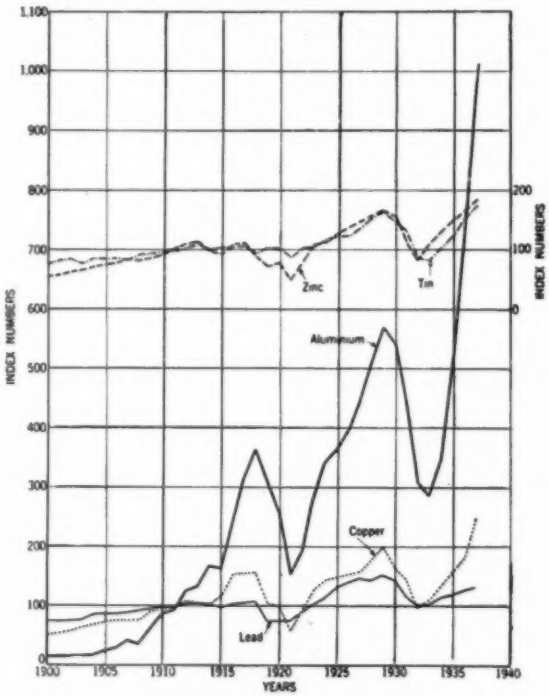


Fig. 3.—Indices of world metal outputs, 1900-1937; base, 1909-1913 average = 100. Left-hand scale: aluminium, copper and lead. Right-hand scale: tin and zinc.

Fig. 2 is a chart which shows the annual world outputs by volume of primary aluminium, copper, lead, tin and zinc over the period 1890–1937. On the basis of volume the world output of aluminium has been much higher than that of tin in nearly all years of the last quarter century, and in 1936 the former was more than that of lead for the first time. The volume of aluminium output has so far continued to be materially less than the volumes of copper and zinc in all years. But, as already pointed out, the average annual rate of increase in output of aluminium has been much greater than the rates of the latter metals over a long period of years. In 1937 world output of aluminium was about 71% of the copper output, and 79% of the zinc output on the basis of volume.

Reference has been made above to the relation of density and selling price of metals. This matter is of special importance in determining comparative costs. Aluminium at 20 cents a pound may appear to be much more expensive than copper at 10 cents, or lead at 6 cents. But at these prices aluminium is the cheapest of the three. The approximate costs per cubic foot at the respective prices are: Aluminium, $34; lead, $43; and copper, $56.

It is understood, of course, that density and the price per unit of volume are only two of the various elements to be considered in choosing materials for specific applications. Nevertheless, the rapid growth of aluminium output has been due in part to the relatively low cost of the metal with regard to bulk.

Indices of Output

Long-term movements of industries may be well depicted by graphs of indices representing relative outputs in successive years. Such graphs are particularly useful for the purpose of comparing trends.

Fig. 3 shows graphs of index numbers for world outputs of primary aluminium, copper, lead, tin and zinc, plotted for the period 1900–1937. The base of the numbers is the annual average output in the years 1909–1913, this being taken as equal to 100. In order to avoid somewhat an inordinate confusion of lines the graphs of tin and zinc

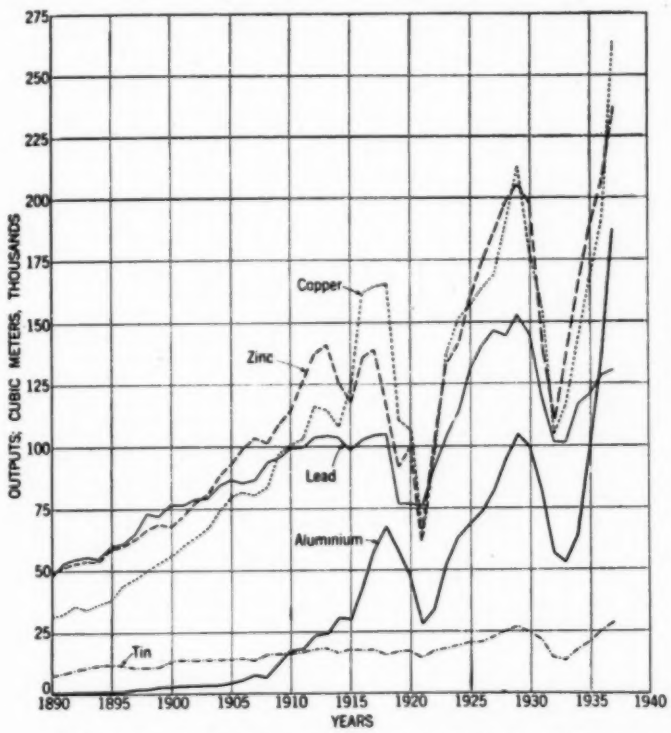


Fig. 2.—Annual world outputs of the principal non-ferrous metals, 1890-1937; volume basis.

are plotted in the upper part of the chart, on the scale at the right-hand side, and those of aluminium, copper and lead are plotted to the same scale, but at the left-hand side. These graphs afford striking evidence as to the remarkably rapid increase of aluminium output, both quantitatively and with relation to that of the other metals.

Copper output in 1929 was slightly more than double the average of the base years, and in 1937 was nearly 2¼ times. But the outputs of lead, tin and zinc have so far been less in all years than twice as much as the corresponding average. Aluminium output in 1929 was about 5·7 times the average of the base years, and in 1937 was more than 10 times.

Consumption

World output of primary metals from year to year is, of course, regularly somewhat larger or smaller than the primary consumption. In general, primary output tends to be more than consumption on the downswing of a business cycle when stocks normally accumulate. And such output tends to be less than consumption on the upswing, at least in the earlier years when excess stocks are on hand. But output may exceed consumption towards the end of an industrial boom. Nevertheless, efforts are made by producers to gauge the trend at all times and to effect a balance. Output may be regulated by individual companies acting singly or through cartel organisations. The present international cartel corporation of the aluminium industry is the Alliance Aluminium Cie., Basel, Switzerland. Leading aluminium producers of most countries, excepting in particular the United States and the Soviet Union, are stockholder-members of this company. Among other objects of the Alliance Aluminium Cie., is one to determine the trend of consumption, and another is to regulate output conformably.

On the whole, world demand for primary aluminium has been forecast remarkably well by the producers, as is shown by the data concerning output, consumption and the development of works capacity. Apart from 1930–1931, world output of primary aluminium has not greatly exceeded the estimated consumption in any year. Still, rather large stocks have accumulated in some producing countries at certain times.

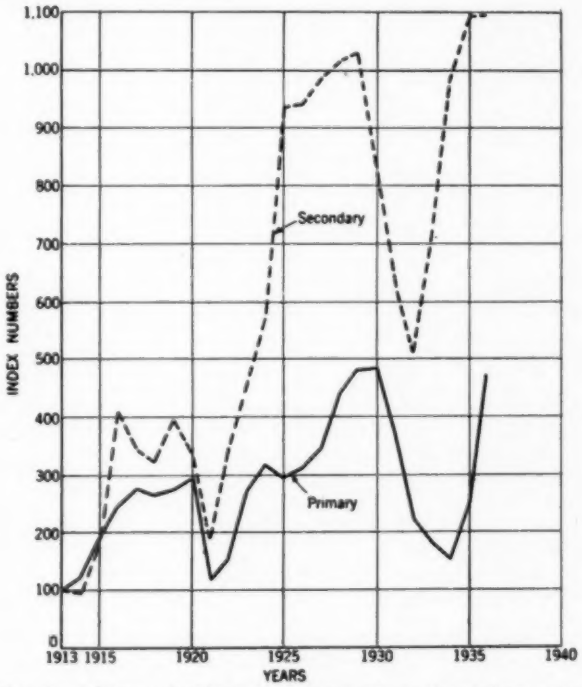


Fig. 4.—Indices of primary and secondary aluminium outputs in the United States, 1913-1936; base, 1913 = 100

Owing to inadequacy of statistics, it is not possible to determine satisfactorily the total consumption of metals year by year in the important industrial countries of the world over a long period. Figures for the actual shipments of primary metals made annually by producers tend to reflect most accurately the quantities of such metals which have passed into consumption either at home or abroad. There is naturally more or less lapse of time between actual production and consumption, depending upon various conditions, and quantities produced in one calendar year may not be consumed until the following year. However, the several circumstances are compensating in the long run, so that the cumulative output of a metal at any time may be considered in a practical way as the virtual consumption up to then. The reference here is to output and consumption of primary metals.

Total consumption of a metal by a country in a year amounts approximately to the sum of primary shipments by domestic producers, plus shipments of secondary metal made from market scrap, plus imports minus exports. Both primary metal, as such, and manufactures processed therefrom by primary producers are to be included in their shipments. Mill or other manufacturing scrap, which is consumed in plants of origin or converted on toll, is regarded as run-around metal, or metal in process of fabrication. But semi-finished and finished products made from market

scrap are to be included with the secondary metal. Shipments from stocks held in importers' warehouses, rather than figures of imports, may indicate more correctly the quantities of imported metal going into consumption. Finally, raw metal for melting, scrap, semi-manufactures and finished goods are to be included in the imports and exports.

As mentioned, the required data for deciding the annual consumption of metals over a long period are lacking. The quantities given in most estimates are too low, since the amounts of secondary material have generally been omitted from calculations.

In 1937 the rank of countries as to total consumption of aluminium (primary plus secondary plus imports minus exports) was probably as follows: United States (first), Germany, Soviet Union, United Kingdom, France, Japan, Italy, Switzerland and Canada. Home capacity for aluminium production is much larger than average consumption in Canada, Norway and Switzerland. The converse situation obtains in Japan and the United Kingdom.

Secondary Metal

In addition to the primary materials large amounts of scrap and secondary metals (as such, or as alloys recovered from scrap and wastes) are regularly utilised in practice. Hence, in reckoning the total consumption of a metal, both the scrap and secondary as well as the primary must be taken into account.

Statistics concerning the quantities of scrap and secondary materials recovered or consumed annually in the principal industrial countries over a long period of years have not been collected except for the United States. The relations between primary and secondary outputs of the several metals in this country over the 24-year period, 1913–1936, are worth noting. Recovery of secondary aluminium for the period was approximately 43% of the primary output; and the recoveries of secondary copper, lead and zinc were about 56, 38 and 29%, respectively, of the corresponding primary outputs. In other words, about 0·43 lb. of secondary aluminium was produced on the average to each pound of primary metal; and the respective quantities in the case of copper, lead and zinc were about 0·56, 0·38 and 0·29 lb. to the pound. The United States has been by far the largest producer and consumer of aluminium, copper, lead and zinc, and the secondary materials have become increasingly important in the metal economics of this country. Secondary metal is a formidable competitor of primary, for, obviously, each pound of old metal used replaces an equivalent quantity of new metal which would otherwise be required.

The comparative development of primary and secondary aluminium output in the United States is represented in Fig. 4. This shows graphs of index numbers for the two outputs. The base is the quantity produced in 1913 taken as equal to 100. Figures of secondary recovery in this country were first recorded for 1913. It is probable that the recoveries in each of the several years immediately preceding were not much different. The secondary statistics for 1937 have not been compiled at the moment of writing, and the chart covers the period 1913–1936.

Fig. 4 shows that recovery of secondary aluminium has increased at a much faster rate than the output of primary metal in the United States. The recovery of secondary metal in 1936 was about 11 times that in 1913, while the primary output was correspondingly about 4·8 times.

Outlook for Expansion

The potentiality for further large expansion of the world aluminium industry is evidently great. In the first place, the aluminium industry is relatively young, as contrasted with other major base-metal industries, and is capable of much growth. In the second place, consideration of two influential factors suggests that output of aluminium will be increased substantially over the near term. These are the constantly improving economic utility of the metal and the autarchic movement outlined below. Likewise, as shown by the significant increase of capacity for production since 1930, the industry is now at a stage of rapid expansion.

Apart from the influence of greatly increased utility developed for the metal through research, changes in the political organisations of some countries and the rise of nationalism since the World War have profoundly affected the world aluminium industry. The far-reaching disturbances caused by unsettled international debts, exchange difficulties and depreciated currencies led governments to the imposition of high import duties, prohibitions and contingents for commodities in general. Such barriers to trade—conspicuously to imports of metals—were erected notably in Continental Europe after the American stock-market crash of 1929. During late years a number of governments have fostered industrialisation and the development of home resources with the object of bettering their economy, reducing or obviating imports, and providing work for citizens. At the same time they have supported programmes designed to increase exports of manufactures. As a heightened expression of nationalistic tendencies, more and more countries have sought to secure maximum self-sufficiency. Furthermore, the persistent fear of war has impelled governments to subsidise the uneconomic domestic production of important metals. Other measures have been undertaken with the view to ensuring adequate supplies of raw materials.

Owing to the remarkable utility of aluminium and the general politico-economic situation just sketched, the desire to produce the metal at home has spread to all countries which consume considerable quantities. The indispensability of aluminium for certain military purposes has been a special incentive in the case of some European nations and Japan. Besides, governments of impoverished or so-called backward countries, particularly those which contain bauxite deposits, have encouraged plans for the domestic production of aluminium in connection with programmes of general industrialisation.

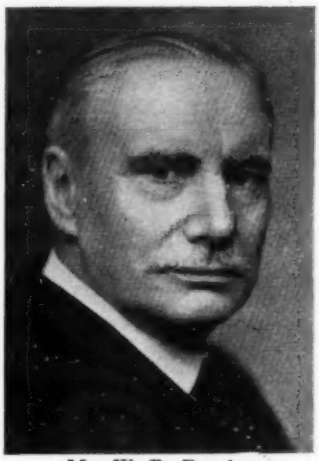
The recently forced use of domestic aluminium by autarchic countries in place of imported metals, notably copper and tin, presents an unusual situation. A number of new applications for aluminium have already been developed as a direct result of such forced use. The effect of this should be to widen the market in general, since some of the forced applications may be economically adaptable in other countries.

Unusual increases in world outputs, above the average annual quantities produced recently, of iron, copper, lead, tin and zinc are evidently not to be expected in future years. But it seems likely that the output of aluminium will continue to increase at a more rapid rate than for nearly all metals, perhaps over the next several decades. The rate of increase in output of magnesium may, however, exceed that of aluminium from now on.

Finally, in respect of long-range possibilities, much greater relative expansion may be expected in the case of aluminium than of other metals as conditioned by ore reserves. Aluminium is the most abundant metal in the earth's crust, and the resources are inexhaustible. Excluding iron and magnesium, other metals are present in comparatively small quantities. At the same time, good reserves of copper, lead, tin and zinc ores are gradually diminishing. The proportionate abundance of iron to aluminium is about 5 : 8, and the supply of high-grade iron ore may be exhausted considerably sooner than the supply of high-grade bauxite.

The Continental Do-All machines are described in a 64-page booklet published by George H. Alexander Machinery Ltd., of Birmingham, under the title of "25 Ways to Cut Machine Costs."

There is much descriptive matter and an ample number of illustrations and diagrams, the basis of the book is to explain these Do-All contour machines by testimonials or case records of saving and advantages made possible by this equipment using a saw band or file band.



Mr. W. R. Barclay.

Some Contributions of Metallurgy to Engineering Progress

The need for the closest possible co-operation between the metallurgist and the engineer was emphasised by Mr. W. R. Barclay in his Calvin W. Rice Memorial Lecture to the American Society of Mechanical Engineers, on June 20, at St. Louis, Missouri, in which he reviewed some metallurgical contributions to engineering progress, particularly during the present century. Some of the main features in his lecture are here summarised.

FROM time to time it is important to endeavour to carry the mind back over certain periods in the advance of technical knowledge and form some kind of broad estimate of what has been accomplished in the application of science to industry in the fields with which we, as individuals or groups, may for the time being be concerned. The young engineer or metallurgist entering industry to-day has, quite naturally, a tendency to take the present position for granted and to regard the attainments of the generation immediately preceding his as normal, and perhaps even commonplace. If such a one could be suddenly transported, even if only for a week, to a quarter of a century ago, and be compelled to work with the materials then available and within the limitations of knowledge then attained, he would, on his return to present-day life, have a very much greater appreciation of what has been accomplished before he arrived on the scene, and, what is even more important, a far more acute sense of its inherent value to his profession.

To-day the engineer who is faced, for example, with a corrosion problem, immediately thinks of such materials, readily placed at his disposal by the metallurgist, as the 18% austenitic stainless steels or some of the non-ferrous nickel-chromium or nickel-copper alloys, and he has almost automatically at hand a vast amount of data, worked out with close accuracy and minute detail, on the properties of these alloys. Such materials have entered into his every-day language. It is not easy for him to realise that had he had to face this problem, say, in the year 1900 instead of in 1938, it would have taken on a vastly more difficult complexion.

The accomplishments of the past are a legacy of inestimable worth, but that worth and value cannot be realised unless the fullest possible advantage be taken of them, to do which requires not only knowledge but a sympathetic appreciation of their aims, the labour expended and the fundamental results which have been achieved. In view of the great progress made in Mr. Barclay's own industrial life, he felt that a general summary of the subject rather than details would arouse interest and create a desire to search for detailed information. He placed definite chronological limits to his address and made the selection on a personal basis, dealing exclusively with developments within his own experience.

In any review of progress in the science and art of metallurgy, and particularly in the development of new and improved products, account must be taken of the profound influence of fundamental scientific research ; and in the contribution of metallurgy to engineering this factor has been particularly evident since the opening of the present century.

An interesting table is given which illustrates what Professor R. S. Hutton terms "Some Milestones in the Advance of Physical Metallurgy."

TABLE I.

1864. Microscopic Study of Metals. (H. C. Sorby).
1867. Electrical Conductivity and Constitution. (A. Matthiessen).
1884. Eutectics. (F. Guthrie).
1885. Modern Microscopic Study of Metals. (F. Osmond and J. Werth).
1887. Thermoelectric Pyrometry. (H. Le Chatelier).
1888–1891. Electric Resistance Pyrometry. (H. L. Callender, E. H. Griffiths, C. T. Heycock, and F. H. Neville).
1891–1921. Alloys Research, Institution of Mechanical Engineers.
1893–1900. French Commission des Alliages.
1892. Laboratory Electric Resistance Furnaces. Pt. 1892, Ni. 1899, Ni. Cr. 1908, W. and Mo. 1911.
1899. Slip Bands. (Ewing and Rosenhain).
1900. Phase Rule Application. (H. Backhuis Roozeboom).
1901. Quenching of Alloys. (C. T. Heycock and F. H. Neville).
1903. Gottingen Researches. (G. Tammann).
1903. Beilby Layer. (Sir George Beilby).
1911. Corrosion Research, Institute of Metals. (G. D. Bengough).
1912. X-ray Diffraction. (Laue and W. H. and W. L. Bragg).
1918–1921. Single Crystals. (J. Czochralski and H. C. H. Carpenter and C. F. Elam).
1919. Precipitation Hardening. (Wilm, 1911).
1921. X-ray Studies of Alloy Structure. (A. Westgren).
1922. Creep at High Temperatures. (J. H. S. Dickenson and National Physical Laboratory).
1923. Superlattices. (Bain). (Borelius, Johansson, and Linde, 1928).
1923. Anodic Oxidation of Aluminium. (G. D. Bengough and J. M. Stuart).
1923. Corrosion and Passivity. (U. R. Evans).
1924. Modern Development of Study of Electrodeposition. (Research Department, Woolwich).
1926. Electronic Structure of Alloys. (W. Hume-Rothery).
1927. Modern Quantitative-Spectroscopic Analysis.
1928. Electron Diffraction. (G. P. Thomson).
1933. Electron Microscope. (E. Bruche).
1934. Superlattices : Theoretical Explanations. (W. L. Bragg and E. J. Williams).
1934. Theory of Alloy Phases. (H. Jones).

Time does not permit an attempt to show how directly some of these "milestones" have influenced practical developments in industrial metallurgy, but attention is drawn to the vital importance of such discoveries as those relating to the microscopic study of metals, thermo-electric pyrometry, precipitation hardening, high-temperature and creep properties, as well as many others affecting not only the development of new alloys, but the improvement of existing ones, and the adaptation of these materials to the special requirements of modern engineering.

Alloy Steels

The greatest metallurgical advance impressed on Mr. Barclay's mind as a young student was the introduction of "alloy steels." He began the study of metallurgy in 1893, only a very few years after the epoch-making work of Riley on nickel steels was published, and has a vivid recollection of the revolutionary effect of this work, not only in regard to its industrial applications, but also as affecting the mental outlook of the metallurgists of that day. The addition of nickel to plain carbon steels not only

improves the mechanical strength of the steel, but greatly facilitates heat-treatment, and the production of uniform and reliable properties. The compositions in general use vary from a nickel content of 1–1·5% to 6%, and within these ranges of composition maximum stress values up to 150,000 lb. per sq. in. or even higher can be obtained. It will be readily understood how greatly the engineer has been helped by such improvements in the properties of his ordinary materials.

Attention is also drawn to the quite extraordinary value of the nickel steels under conditions of use at abnormally low temperatures. Below room temperatures the ordinary carbon steels tend to become brittle. The addition of nickel exercises a profound influence in inhibiting this tendency, and a 3% nickel steel will retain its toughness down to temperatures of, say, 100° C. or lower.

Great development of alloy steels has been brought about not only by the natural progress of research and by the demand of the engineer for materials of greater strength, but as a result of the fundamental practical difficulties met with in the heat-treatment of ordinary carbon steels, in obtaining a really satisfactory combination of strength with toughness and ductility.

Although the earliest beginning of what are now termed "high-speed steels" may be plainly traced back as far as Mushet in 1857, yet in a very real sense they belong to the advances of the present century. The basic composition of all such steels depends on the introduction of chromium and tungsten. In this connection, however, the employment of the elements vanadium and molybdenum must not be overlooked.

The relatively modern development of the use of copper as an alloying element in steels is also evidence of progress. A number of alloy steels, some of which have been developed, contain copper up to 1%, usually in conjunction with nickel or manganese and chromium. Such steels have been found to possess valuable properties, particularly with regard to yield-point and ductility. There is also some evidence that these alloys show improved resistance to certain types of corrosion.

It is difficult to assess the exact value to engineering progress of the enormous development of alloy steels, but it is obvious that the commercial production of steels possessing a maximum tensile strength of the order of 200,000 lb. to 250,000 lb. per sq. in. has, by increasing the strength-weight ratio, enabled designers to effect material reductions in the weight of engineering structures. A further factor of no less importance than the saving of weight in modern engineering construction is the longer life now made possible. In this direction the value of the work of research metallurgists in increasing our knowledge of such important factors as mechanical- and corrosion-fatigue; of creep under stress at both normal and high temperatures; of the factors which influence brittleness in steels, machining properties; and above all the intensive study of reactions of corrosive agents, whether atmospheric or other, have all rendered incalculable service to modern engineering.

On the general subject of corrosion and heat-resisting steels, Mr. Barclay quotes briefly J. H. G. Monypenny, whose book on the subject has become a classic in the English language. His conclusions are summarised in the following terms:—"As a result of his investigations on these austenitic steels, investigations carried out over a period of years and to a large extent independently of the work of Strauss and Maurer, the author considers that an alloy containing 15–16% chromium and 10–11% nickel possesses the best all-round combination of properties desirable in such a steel for most of the purposes for which it might be used."

Another illustration of the patient, systematic and skilled investigatory work which lies behind all the metallurgical advances is given in a brief recount of the story of the discovery of stainless steel, as recorded by Harry Brearley. Like many other such discoveries, it was superficially an accident, but behind it lay many years of experienced research work, together with the ability to make minute and careful observations, which is to a large extent the secret of all scientific discovery.

Another outstanding development of recent years, and a further example of the value of alloying additions to ferrous metals, is found in the improvements effected in cast iron by the addition of nickel, either alone or in combination with other alloying elements.

Non-Ferrous Metals and Alloys

Particular reference is made to the remarkable development of alloys of the nickel-copper type. Nickel has a quite extraordinary influence on copper, even when added in only small percentages. The curves (Fig. 1) furnish one example of this, showing that a 2% nickel addition to copper results in raising its strength at high temperatures not only appreciably above that of copper itself, but also above that of several of the commoner copper alloys which at normal temperatures are definitely harder and stronger.

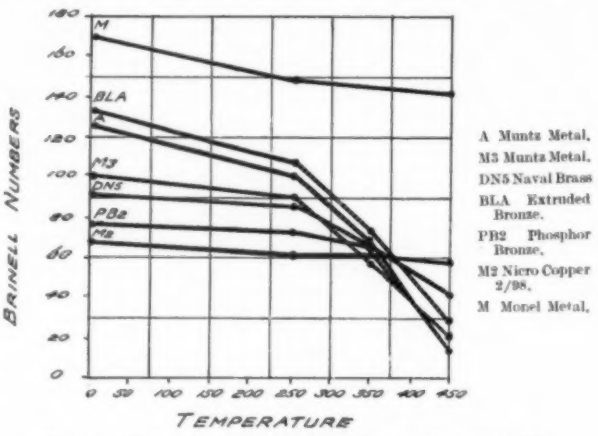


Fig. 1. Brinell hardness of various alloys at high temperatures.

A striking example of a metallurgical contribution to engineering progress in the nickel-copper series of alloys, is the applications of 70/30 cupro-nickel to the solution of the condenser tube corrosion problem. The first alloy used was the 80/20 composition. It was speedily found that this tube presented considerable advantages over the brass tube. Further experimental work indicated, however, that an increase in the proportion of nickel resulted in a definite further increase in corrosion resistance. Ultimately, in 1926, the British Admiralty adopted the 70/30 cupro-nickel condenser tube as standard for all new ships, and this practice has now been followed by practically all other Admiralty departments in the world. Investigations also resulted in considerable improvements in the cheaper brass condenser tube. A copper-zinc alloy with the addition of up to 5% aluminium, known as aluminium brass, has effected a very considerable improvement in this field of corrosion-resistant materials. Although cupro-nickel still retains its superiority, there are many conditions where corrosion attack is liable to be less severe, under which the aluminium brass tube is giving reasonably satisfactory results. The use of aluminium brasses has been followed by the introduction of aluminium-containing cupro-nickels. One of the resulting alloys, that containing 1·5% aluminium, is especially mentioned.

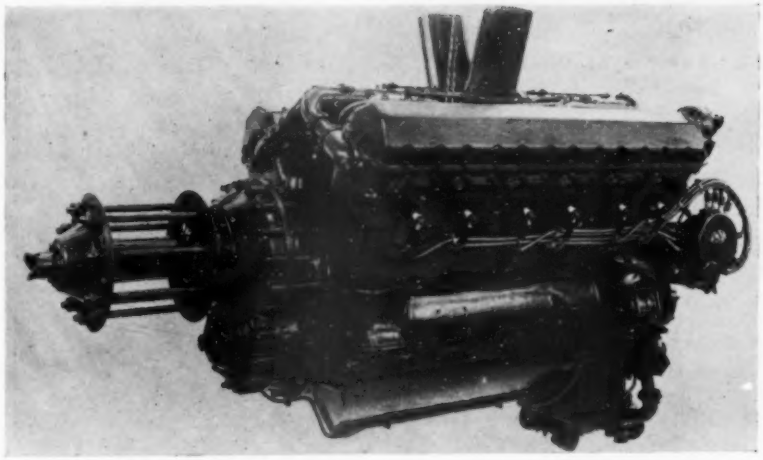
Turning now to the nickel-rich end of the nickel-copper series, Monel metal and its applications are too well known to require any lengthy description here. Suffice it to say that within the range of compositions 60–70 nickel is obtained the optimum mechanical properties of the series, combined not only with a high ductility, but with exceptionally good corrosion-resisting properties. It is the latter which have proved the greatest single factor in the

widespread applications of Monel metal in modern engineering. Among modern developments in the Monel type of alloy, the value of aluminium additions has been demonstrated, and in "K" Monel, which is an example of an aluminium-containing nickel-copper, is an alloy susceptible to heat-treatment, which when correctly handled is proving most successful in giving long life and resistance to corrosion attack under the severest conditions.

Another series of most valuable engineering alloys which have been almost entirely developed within the present century is the nickel-chromium alloys. These are not so simple in metallurgical constitution as the nickel-copper type, but fortunately the nickel-rich end of the series furnishes a large variety of industrially useful alloys, particularly for electrical-resistance and heat-resisting purposes. The most typical alloy is that containing 80% nickel and 20% chromium. There are, however, a number of other valuable alloys of this type, in which the nickel content varies between 65 and 95%. Of these, an alloy, developed by the International Nickel Co. under the trade name "Inconel," deserves special mention. It consists of approximately nickel 80–82%, chromium 12–14%, iron remainder, and possesses extraordinary properties of resistance both to heat and corrosion.

Appreciable improvements in the heat-resisting properties and "life" of these nickel-chromium alloys have been effected recently by additions of aluminium and/or certain of the rare earth metals, and the service given to-day by these alloys is greatly in advance of that obtainable even four or five years ago.

One of the most notable series of alloys developed for special engineering requirements is the quaternary nickel-aluminium-cobalt-iron group developed during recent years for magnetic uses. At first these alloys were essentially nickel-aluminium steels containing approximately 25% nickel with 13% aluminium, but more recent research work has shown that appreciable advantages are conferred by the addition of cobalt, the approximate composition being 20% nickel, 10% aluminium, and 10% cobalt. The revolutionary advances that have been made in telegraphic and telephonic engineering by the introduction of such alloys as "Permalloy," "Mumetal," etc., are also commented upon.



Rolls-Royce Kestrel engine in which nickel steels, "Y" and RR aluminium alloys are used.

Aluminium and Light Alloys

The development of alloys of aluminium have been mainly inspired by the demand of the engineer. Throughout the present century, metallurgists in many countries have systematically sought to improve the properties of aluminium by means of the addition of alloying elements. The first and most outstanding achievement in this direction was the production of Duralumin in the year 1911, by Wilm. This achievement opened up what has now become a very important field, the heat-treatment and precipitation hardening of non-ferrous alloys, since the mechanical properties of Duralumin are essentially dependent on heat-treatment processes analogous to those used in steel.

Some years after the introduction of Duralumin, and as the result of intensive experimental work in the National Physical Laboratory, an alloy known as "Y" alloy, possessing somewhat similar properties, was developed, and has reached a position of considerable engineering importance. In chronological sequence, were developed a group of aluminium alloys resulting from a number of researches carried out in the laboratories of Rolls Royce, Ltd. These alloys, which have become known as the "RR" series, have achieved considerable industrial importance, and have contributed to the increased efficiency of the internal combustion engine, particularly for aeronautical requirements.

The original "RR" alloys were developed mainly for foundry purposes and for die-castings. They are particularly adaptable for both purposes, but later compositions have been designed for wrought products, and are made available in a large variety of forms, such as sheets, tubes, bars, sections, forgings and drop stampings. One outstanding advantage of the "Y" and "RR" type of alloys is their high thermal conductivity as compared with cast iron—the only material formerly available, the aluminium alloys having about three times the thermal conductivity of cast iron. The advantage of this factor is obvious when it is realised that the density of the aluminium alloys is only about one-third that of cast iron.

Magnesium Alloys

The development of magnesium alloys during the past ten years has been probably one of the most spectacular in the field of non-ferrous metals. Research work on these alloys has proceeded intensively and is still receiving the attention of research metallurgists in every part of the world, especially in Germany. One direction in which research work has been appreciably successful is in finding additional elements which inhibit its reaction to corrosion by sea-water. Of the elements available, manganese is probably the most important, and is usually added to magnesium alloys in the proportion of ½ to 2½%.

In the cast form, magnesium alloys usually contain aluminium and zinc. For alloys in the wrought form—*i.e.*, semi-manufactured—those containing aluminium without zinc are by far the most important, and in the form of extruded rods, alloys containing 10–12% aluminium have a tensile strength quite comparable to that of the aluminium alloys themselves. Of developments of still more recent date, mention must be made of the addition of silver, and particularly of some of the rarer alkaline earth elements, of calcium and cerium. The combination of silver and calcium has considerable value in increasing the resistance of magnesium to oxidation, and the addition of cerium increases strength of the material at high temperatures.

Attention is directed to the important fact that vital improvements have been made possible in the quality of die-cast products by the use of the appreciably purer raw materials which are now placed at the disposal of manufacturers. The problem of intercrystalline corrosion, which was exceedingly serious in earlier die-castings, was shown some time ago to be largely due to the presence of small quantities of impurities, mainly lead, cadmium and tin, which are of course often found even in the highest qualities of refined zinc.

Powder Metallurgy

This development is of both actual and potential importance to engineers, and although only in its initial stages, must receive at least brief mention in this survey. It has really brought into existence an entirely new technique in the production of metals and alloys in forms suitable for the engineer, and has enabled the metallurgist to manufacture metallic products which hitherto have not been producible. An outstanding example of this new technique is that of ductile metallic tungsten. By pressing tungsten powder at a high temperature it is possible to produce a perfectly sound ingot which can subsequently be forged or swaged and drawn or rolled into wire or strip. This technique has been applied not only to tungsten itself, but to alloys containing it, some of which are given notice.

A recent application of these alloys is for balancing crankshafts for internal combustion engines used in racing cars, and indeed for a whole variety of engineering purposes. In addition to the properties peculiar to themselves, these alloys possess extraordinary resistance to sea-water and other analogous corrosion agents. In the purely non-ferrous field of powder metallurgy, one of the most important industrial developments up to the present is the production of bronze bearings from nickel, copper, and tin powders. These bearings are porous, and may therefore be impregnated with oil to the extent of 25 to 40% (by volume). They are already finding some engineering applications, notably in the automobile field.

In conclusion, Mr. Barclay considered that one of the greatest factors of progress is the closest co-operation between the metallurgist and the engineer. The discoveries of the metallurgist, whether on the purely scientific side or in industrial development of new or improved metallic alloys, depend almost entirely on the engineer for their ultimate usefulness in the service of man.

New Industrial Uses of Silver

SOME time ago a research project, sponsored by a group of leading American silver producers, was initiated for the purpose of investigating thoroughly all aspects of the silver industry. Research along different lines is being carried on at various centres, the work including investigations into the bactericidal, chemical, fungicidal, physico-chemical and thermal properties of silver, as well as its electrical characteristics and metallurgical possibilities. The success which has attended the venture may be judged from the first series of results published* ; these show that progress has been made which may be of definite value to the silver industry.

A brief review of these results† indicates that a very profitable line of research has been that dealing with the anti-friction properties of silver and silver alloys. Pure silver gave very good results. Steel-backed bearings lined with nearly pure silver are finding an increasing use in industry, and have been, in fact, adopted as standard equipment in certain aeroplane engine parts. Experiments have also led to the development of better adhering methods for the electro-deposition of silver on steel and to an improvement in technique for the co-deposition of a number of elements with silver.

For rotating electrical contacts, silver slip-rings and silver-graphite brushes have been found more effective than those of carbon and copper-graphite ; the contact voltage drop is appreciably decreased, and there is less polarity effect. The value of silver salts as fungicides has been proved, and certain salts have also been used with success in water sterilization, particularly in fish hatcheries.

The permeability of hot silver to oxygen has also been investigated, and results have shown that this property may be employed successfully in air fractionation, as, for example, in the enrichment of blast-furnace air. The solubility of oxygen in molten silver has also been studied. As a catalyst in the oxidation of ethyl alcohol silver has given very satisfactory results.

Research is proceeding along a number of other lines, and results are to be made public as they become available.

* *Journal of the Franklin Inst.*, 1938, 225 ; No. 2, 227–229.
† *Bull. Imp. Inst.* 1938, 36 ; No. 2, 209–210.

Correspondence

The Editor, METALLURGIA.

Accurate Mechanical Terms

Sir,—The following comments on the expressions " Ferrocolumbium," " Ferroniobium," and " Ferrotantalum " may be of interest to your readers, particularly so since frequent inquiries have been received about these terms. Ferrocolumbium and Ferroniobium are used to describe the same element similarly to other cases, such as wolfram and tungsten. Since practically all inquirers have used Ferrocolumbium (Ferroniobium being the continental term) I shall in turn use that expression.

Ferrocolumbium is a standard alloy of iron and columbium analysing 50 to 60% of columbium, with not more than 6% tantalum. Tantalum is considered as an impurity, and the alloy is purchased on the basis of columbium content. Within the past year, many technical articles and advertisements have appeared in which the term " Ferrocolumbium " has been falsely applied to mixtures of columbium and tantalum, even when the content of tantalum exceeded that of columbium. In extreme cases, particularly where the use of columbium has been specifically recommended, such designations are almost tantamount to misrepresentation. The restriction of the term " Ferrocolumbium " to an alloy containing at least 10 times as much columbium as tantalum would go a great way towards clarifying the terminology for your readers. The expression " Ferro-Tantalum-Columbium," or " Ferro-Columbium-Tantalum " could then be used for those alloys which contain simultaneously large percentages of both elements.

Such confusion, as sometimes does exist in modern metallurgy is frequently due to loose language and inaccurate terminology, and in drawing attention to this subject you will render your readers a definite service. At the same time, you should be able to help your advertisers in more closely defining their products and their applications, which would naturally make your mutual efforts effective.—Yours faithfully,

HOWARD BIERS.

Brussels, June 16, 1938.

A Large Hot Water Storage Tank

THE largest tank yet constructed in this country from " Everdur "—the copper-manganese-silicon alloy developed in Great Britain by I.C.I. Metals Ltd.—was recently fabricated by Messrs. Alexander McAra, of Dundee, for the Broughty Ferry and District Steam Laundry Ltd.

Four hot-rolled " Everdur A " sheets (11 ft. × 4 ft. × 9 G) and two circles of the same material (5 ft. 7 in. in diameter × 7 G), were used in the construction of this tank, which is 12 ft. long and 5 ft. in diameter. It was tested under a pressure of 45 lbs. per sq. inch. It will be noticed that the material was used in lighter gauges than could safely have been specified for steel, no allowances having to be made for corrosion during service.

The vessel was welded throughout by the oxy-acetylene process, using 28 lbs. of " Everdur A " 6 G welding rod. The satisfactory strengths of the welds were confirmed by tests on sample welds. The specimens, made from plates similar to those used in the construction of the tank and finished by cold hammering in the same way as the seams, showed tensile strengths of 26 and 26·1 tons per square inch, and elongations on 2 in. of 37% and 36% respectively. The fracture in each case occurred in the parent metal and not in the weld, showing that the strength of the joint was equal to that of the parent metal.

Resistance Welding and Developments in Electrode Materials

By P. MABB

Spot welding is now widely used as a fabrication process, but frequently insufficient attention is given to details necessary in obtaining successful welds. In this article some important factors are discussed which are given scant attention by those responsible for the control of this method of welding.

DURING the past decade the practice of jointing metals by means of spot-welding processes has become exceedingly popular, and now form a recognised method of fabrication processes. The reason is not far to seek, for, in the case of weldable metals, spot welding is frequently a cheaper means of making a joint than riveting. In the case of riveted joints expense is incurred in producing the rivet, drilling the rivet holes, ensuring alignment of the holes in each member to be joined, and in riveting the two parts together. In comparison, a single operation of the spot welder is all that is necessary in spot welding to produce a similar effect. Moreover, a good spot weld is stronger than its equivalent riveted joint ; because with the former the opposing surfaces are completely fused together, forming contact to a degree which the latter cannot achieve. Although spot welding is widely employed, frequently insufficient attention is given to many details which demand attention if successful welds are to be made, and brief mention will be made of the more import of these.

In general, surfaces to be welded will possess an irregular contour. Quite a large proportion of the work will consist of parts which have been formed to the required shape, and therefore perfect fits are seldom in evidence. Unless sufficient pressure is exerted by the machine to ensure that good contact is secured between the two surfaces immediately beneath the electrodes, the current will have to traverse a relatively long path through an area in contact remote from the electrodes, and thus create a weld deficient in strength. Under these conditions consecutive welds will vary in strength. If it is impossible to procure flat surfaces without expensive machining operations, one of the pieces, if of a suitable thickness, can be indented, thus raising a small point or projection which ensures contact being secured. Generally this point should be formed on the thicker of the two pieces, thereby making some attempt at equalising the heating effect and localising the current. In all cases the release of the pressure should be delayed until the weld has cooled sufficiently to overcome the tendency for the parts to spring apart.

Surface condition also plays an important part in determining the efficiency of the junction. The presence of dirt, scale, oxide and other foreign matter between the junction surfaces is objectionable. Apart from weakening the weld due to the inclusion of these foreign bodies, additional resistance is created, which may produce such a rush of current as to produce an arc and burn the metal. Further, the welding of dirty metal will adversely affect the life of the electrodes.

There are other important factors which exercise a marked influence on the character of the weld. The chief of these are : electrical resistance ; specific heat ; thermal conductivity and latent heat of fusion of the metals to be welded, all of which are fixed.

The chief variables are : the intensity of the current, welding time, pressure and electrode shape. Modern developments in spot-welding machines have all been directed towards the perfection of devices to control the welding time within very small fractions of a second by mechanical, electronic tubes (thyratron) or electro-magnetic devices. Control units of this character have been introduced with great success. Pressure arrangements have also been made flexible to permit of a wide range and transformer design has kept apace with the demand for intense current. From the equipment side it can be said with certainty that spot-welding machines are now available to meet the most exacting needs. In connection with some metals commonly spot welded physical constants are given in Table I.

TABLE I.

CHARACTERISTICS OF MATERIALS COMMONLY SPOT WELDED.

Metal or Alloy.	Condition.	Hardness Vickers Pyramid Numeral.	Melting Point. °C.	Specific Heat Cals. per Gram.	Specific Resistance at 20° C. Microhms per cm. Cube.	Thermal Conductivity. Cal./cm.³/° C per sec.
Aluminium	Soft	20	658	0·214	2·85	0·504
Brass, 70/30	Soft	75	960	0·088	6·99	0·26
Copper	Soft	55	1,083	0·094	1·78	0·92
Phosphor Bronze	Soft	120	1,010	0·9	5·10	0·29
Monel Metal	Annealed sheet	120	1,350	0·127	42·5	0·06
Nickel Silver, 18%	Annealed sheet	115	1,080	0·09	30	0·07
Mild steel	Soft	120	1,530	0·117	20	0·115
Stainless Steel, 18/8	Soft	140	1,450	0·117	72	0·033
Platinum	Soft	90	1,773	0·32	10·5	0·166
Palladium	Soft	90	1,555	0·052	10·7	0·168
Gold	Light Drawn	50	1,063	0·032	2·4	0·70
Silver (99·9)	Light Drawn	110	961	0·056	1·6	1·00
10% Iridio Platinum	Hard	230	1,810	—	23·6	·074
30% Iridio Platinum	Hard	290	1,885	—	33·1	·05
Platinum 6 / Gold 69 / Silver 25	Soft	100	1,120	—	16·8	—
Gold 70 / Silver 30	Soft	90	1,060	—	10·4	·36
Palladium 60 / Copper 40	Hard	240–280	1,230	·07	35·0	—

A neat appearance is very desirable in spot-welded work, too often spot welds are seen as deep indentations, with a splashy contour and badly cratered outline. It be may taken as axiomatic that an untidy-looking spot weld is a poor one. The area of weld will be governed by the size of the electrode tip and the plasticity of the metals to be welded. The volume of the weld will be governed by the heat input and pressure exerted through the electrodes. These factors, given adequate consideration, enable satisfactory joints to be made with a pleasing appearance.

The design of the electrodes plays an important part in the economy and efficiency of spot welding. The all-important feature is to ensure adequate cooling of the tip, and to design the electrode in a manner to assist cooling. All electrodes should be water cooled and the feed tube positioned close to the end of the water bore to ensure adequate circulation of cold water with the avoidance of steam pockets. Overheating of the electrodes produces mushrooming with attendant increases of contact area.

It is obvious that it is essential the electrodes should possess high electrical conductivity and high thermal conductivity. The selection of copper for this purpose was a natural choice. On the other hand, the conditions of service are extremely arduous, and the metal used should possess other characteristics. The qualities exhibited by an ideal metal for use as electrodes may be summed up as follows :

1. Adequate electrical and thermal properties.
2. Freedom from burning and pitting.
3. High resistance to mechanical wear.
4. Long-service life.

No one metal or alloy possesses these characteristics to an optimum extent, but the problem of improving the life of electrodes has been given considerable study, and a number of proprietary alloys are now available for which various claims are made. The basis of most of these alloys is copper, and the alloying element either silver, cadmium, tungsten or a combination of these. Alloying elements selected will have regard paid to the effect they will exert on the conductivity of copper, and the field is, therefore, somewhat restricted.

Consideration of the copper-silver diagram reveals that with silver present, except in small amounts, the alloy will tend to become pasty, if a temperature in excess of 778° C. is attained, the alloy above this temperature consisting of the β phase plus liquid. Copper-cadmium alloys behave similarly. Alloys with cadmium in excess of small amounts, when heated above 549° C. will consist of the α phase plus liquid. Electrodes made from these alloys, if the silver or cadmium content is greatly in excess of 2 and 3%, respectively, and they are heated above the temperature limits given above, will tend to mushroom up badly. Even with adequate cooling devices, it will be impossible to keep the contact area of the tips cold, and with the pressure employed the electrode must wear. Experience has shown that the degree of wear is much less than with ordinary copper electrodes. Moreover, these alloys are capable of being work hardened to a greater degree than plain copper with the same percentage reduction. As is well known, the presence of silver has the effect of raising the softening point of copper by some 100° C. In Table II particulars are given of alloys containing cadmium or silver which are available on the market. A ternary alloy is also included. The hardness of this alloy is considerably in excess of that exhibited by the usual run of hard-drawn copper rods.

TABLE II.

COMPOSITION AND HARDNESS VALUES OF ALLOYS USED FOR ELECTRODES.

Supplier.	Composition. %.				Hardness Vickers Pyramid Numerals.
	Copper.	Silver.	Cadmium.	Tungsten.	
A	98·8	—	1·2	—	96·2
B	99·1	—	0·9	—	122
C	96·4	2·28	1·2	—	196
D	3·8	—	—	96	456
D	39·8	—	—	59·8	212
E	41·2	—	—	58·8	421
F	93·4	6·51	—	—	135
F	99·40	—	0·55	—	130

Although by no means the ideal desired, copper-cadmium, copper-silver, and copper-cadmium-silver electrodes exhibit greater endurance than those of copper. Less mushrooming occurs and dressing time spent in trimming up the electrode tip is reduced. A saving in electrical energy is also achieved by reason of the tip retaining its shape and concentration of the energy to a small area is secured.

Cintered alloys of copper and tungsten have also been employed for use as electrodes. Possibly one of the best is that which contains approximately 60% tungsten. In rod form the material has a steel-like appearance on the outside, but cut faces are brass-like in colour. This material is not easy to machine, but does not present insuperable difficulties in turning or milling operations. The specific conductivity is considerably lower than the value given by copper, but even so, no interference occurs in effecting welds. The material does not really oxidise and gives extremely long life. One of the disadvantages found in the use of this material is the possibility of fracture occurring under heavy pressure. This difficulty can be overcome by suitably housing the tip. Varying degrees of hardness are obtainable in these materials, samples have been received with hardnesses of 193 and 400 V.P.N. The harder alloy gave the best results.

Recent developments on the continent have produced a number of cintered materials which may be employed as electrodes where extreme conditions of wear have to be withstood. These materials are generally produced as discs, and require to be let into a copper electrode holder. They can be brazed into position with silver solder. The brazing operation can be carried out on a spot-welding machine, and to avoid oxidation hydrogen can be fed to the parts to be brazed through a tube bent round the parts and perforated on the inside of the bend. The hydrogen will ignite and prevent air reaching the parts. One interesting material examined was found to contain: titanium 35.76%; nickel, 9·1%; cobalt, 19·89% and molybdenum 35·22%. The discs were intensely hard and gave values ranging between 1,250 to 1,500 V.P.N. The hardness values are comparable to those obtained on cintered tungsten carbide cutting materials. In common with tungsten carbide they are relatively brittle, and therefore must be suitably housed if breakage is to be avoided.

In the foregoing attention has been directed to features which all too frequently are given but scant attention by those who are responsible for the control of spot-welding operations. No attention has been paid to the electrical design involved in machines for the reason these are fully described by makers and the limitations and purpose of the different types of machines made are clearly set forth in machine specifications. For some extraordinary reason users of this process are prone to allow the conditions under which welding is to be carried out to be determined by trial-and-error methods. In most up-to-date factories the sequence of operations, processes to be employed, machine, machine setting and type of tools to be used are fully listed on the planning sheets for most shop operations, and it is therefore strange that spot welding should be more or less indifferently controlled.

The classification and pooling of experience gained in the use of different metals and alloys for electrodes has not yet made any appreciable headway. Until comparative data has been established rapid development of alloys and materials for this class of work will not occur. At the same time steps have been made, and a range of materials is available which enables better work to be done and economy in upkeep of electrodes to be secured.

"Stannising"

A NEW process for coating brass, copper, iron, zinc and other metals with tin is applicable to fabricated articles of the most complicated shapes. The method consists in suspending the articles for a few minutes in an atmosphere of hydrogen and the vapour of stannous chloride.

The articles are washed clean of grease with soap and water, or a solvent, and suspended at 500° to 600° C. for a few minutes. In contact with the metal surface the hydrogen reduces the stannous chloride to tin, which then alloys with the article. The thickness and the composition of the alloy formed depend upon regulation of the temperature and time of exposure to the "Stannising" vapour, and upon its proper circulation. By passing the gases from the stannising character into molten tin they are easily and continuously regenerated for recirculation; the apparatus for the process is simple.

Many of the tin alloys, particularly with copper, are extremely hard, and, in consequence, wear-resistance, far in excess of that obtainable with pure tin appears possible. A bright hard surface of speculum metal, such as has been used in the past for mirrors, can be obtained. Coatings can be applied to rough, threaded or irregular surfaces, and machine parts can be built up to size again after first machining slightly to undersize. From the porosity point of view the "Stannised" coatings on sheet-steel strips were better than those on ordinary tinplate.

The details of the method and a discussion of its mechanism are fully described by B. W. Gonser, D.Sc., and E. E. Slourter, M.Sc., in a publication issued by the International Tin Research and Development Council. Copies may be obtained free of charge on application to the Secretary, International Tin Research and Development Council, 378, Strand, London, W.C. 2.

Some Recent Developments in the Iron and Steel Industry in Britain

By A. McCance, D.Sc., and T. W. Hand

In reviewing the development in British iron and steel works at the International Engineering Congress recently held in Glasgow, the authors limited their consideration of the subject to the newer plants, which have particular economic significance in both local and national aspects. An abridgement of the paper is given in this article.

ASTONISHING progress in all sections of iron and steel manufacture has been witnessed in the past twenty years. The necessity for some development arose from the increasing costs of labour and fuel. The introduction of the eight-hour day in Britain led to a substantial increase in the labour cost of steel-making, and started an intensive scrutiny of all metallurgical and engineering processes for the purpose of reducing the burden. This development endeavoured to eliminate non-productive time in all conversion operations and to utilise waste products. As the magnitude of the economies possible was realised, the study of production methods became more and more intensified, and at the present time it cannot be said that they have yet reached their full achievement. The result has been a very extensive mechanisation throughout the industry and a successful development of continuous processes, especially for rolling. Certain of the newer plants will be discussed with some regard to geographical distribution and the influence of this on the type of plant adopted.

Scotland

Plants in this area have been equipped with machinery specially suited to the production of all classes of steel used in ship and engine construction. Scottish iron and steel works come under a single well co-ordinated control, and as the resulting regrouping has necessitated many changes in equipment, the principal units of plant are given in some detail.

The combined plant of the Clyde Iron Works and Clydebridge Steel Works of Colvilles, Ltd., comprises coke-ovens, blast-furnaces, and steel works, the latter now being equipped to receive a large proportion of its raw material in the form of liquid iron, which will be transported over a bridge now being built to span the Clyde between the works. The coke-ovens, of which there are 68, are 16 in. wide, with a throughput of 23 tons of coal per 24 hours, giving a total of 1,000 tons of coke per day. They will be fired with blast-furnace gas. In the new scheme at Clyde Iron Works, both the electrostatic and the disintegrator systems of gas cleaning will be in operation.

In addition to one 250-ton furnace, constructed six years ago, it is now proposed to erect two blast-furnaces to deal with 500 tons per day each, as this size is considered best suited to local steel works conditions. In the case of integrated works, where the steel works depend on the use of waste gases for fuel, it is inadvisable to have fewer than three furnaces in the blast-furnace plant.

The stoves at Clyde Iron Works will be of the high-efficiency type with three brickwork zones, permitting two-stove operation for each furnace. Adequate facilities will exist for concentrating fine material, and a pig-casting machine will ensure the production of sandless iron during the week ends. The plant now under construction will be representative of the latest practice throughout.

The plate-rolling plant at Clydebridge Works has been further improved by the installation of a complete reversing electric drive to the slabbing mill, which serves to " break down " the ingot to intermediate size suited to the plate-rolling mill. Contrary to more usual practice, but having regard to the relatively low-speed requirements of the slabbing mill, advantage has been taken of the possibility of installing a driving motor of moderate size, coupled to the mill through high-efficiency reduction gear of 2 to 1 ratio. All gears are totally enclosed, and, together with bearings, are flood-lubricated from a central oil-circulating system.

The product of the slabbing mill, after reheating, is conveyed by feed tables to the Lauth-type plate mill, which has rolls 9 ft. in length. This mill is of the continuously running 3-high type, and is probably the first of its type to be provided with a reversing motor. The mill, together with its auxiliaries for levelling, cooling, and final shearing of the cold plate to specified dimensions, comprises all known mechanical and electrical devices for ensuring maximum economy of power, and is distinguished by the almost complete absence of human effort. The plant is devoted principally to the production of rolled plates for shipbuilding purposes, and is capable of a sustained average weekly output of 4,500 tons of plates, ranging from $\frac{3}{16}$ in. to $1\frac{1}{4}$ in. in thickness, and up to 8 ft. 6 in. wide.

The heavy plate-rolling mill plant at Colvilles, Ltd., Dalzell Steel Works, Motherwell, is of unusual interest, in that practically every part of the plant has, during the past few years, been remodelled with no real interruption of production. The plant comprises a powerful slabbing and blooming mill serving a two-stand plate mill of reversing type, with all necessary auxiliary services. Excepting only certain mills devoted to the production of armour plate, these mills, when considered in relation to weight and size of product, constitute the most powerful British examples of their respective types.

The slabbing mill deals with ingots of from 7 to 30 tons in weight, and in addition to producing a full range of slabs for subsequent use at the plate mill, also provides large blooms for outside sale or re-rolling into other products. The shear at this mill is considered to be the most powerful unit of this type in existence, and will hot-cut slabs up to 66 in. wide and 18 in. thick.

The reversing plate mill comprises two stands of rolls 14 ft. and 9 ft. 3 in. long respectively, all rolls being 44 in. in diameter. The driving equipment of this mill has, during the period of general reconstruction, presented many problems of unusual engineering interest. Careful study of surroundings confirmed, however, that as an existing modern boiler plant was available, the use of this, in conjunction with a works' power station and a steam accumulator, provided almost ideal conditions for an economical steam-engine drive for the mill, and this was accordingly adopted, the engine being of twin tandem compound condensing type, with cylinders $38\frac{1}{2}$ in. and 55 in. in diameter, and a 60-in. stroke.

Practice at these mills is to pass all slabs through the wide rolls and finish down to desired plate thickness if too wide for the adjacent rolls. All plates which will pass through the latter, however, are finished there after being roughed down in the wider rolls. Normally the mill produces plates form $\frac{1}{4}$ in. to 2 in. in thickness, and up to 13 ft. 6 in. wide, but slab plates of considerably greater thickness can be equally well rolled, as also slightly greater widths for

short plates, such as are required for cutting into circles for boiler ends, etc.

The merchant bar and wire rod mill at Dalzell Steel Works is of considerable local significance in being the first mill in Scotland to incorporate the continuous system of rolling. The material to be rolled passes from the stock-yard through the reheating furnace, and, on being ejected from the latter, immediately enters the first roll stand of the continuous roughing mill, the successive roll stands of which are progressively speeded up for passing the increasing length of the bar. The mill is supplied from larger mills with billets 2 in. to 3½ in. square, and produces bars of a diameter of $\frac{5}{16}$ in. to 1¼ in. in straight lengths, or rods of a diameter of $\frac{3}{16}$ in. to $\frac{5}{8}$ in. in coils. Small sizes, when rolled for straight lengths, are much longer than could be reasonably accommodated on a cooling bed, and an automatic shear is therefore installed between mill and cooling bed to cut the bar into suitable lengths during its passage through.

South Wales

Having regard to the importance of South Wales as the centre of the sheet and tinplate industry, the recent developments which have taken place in the reorganisation and reconstruction of iron and steel works plant are of particular interest. In a general sense, it can be stated that sheet bar, the semi-finished product supplied to the sheet or tinplate mill, has in the past almost invariably been produced in moderate tonnages from comparatively small ingots, the total requirements of the district having been realised from many medium-size mills, usually reversing and in some cases of three-high continuously running type.

Resulting, however, from the amalgamation in recent years of the heavy steel interests of Guest, Keen and Nettlefolds, Ltd., with Baldwins, Ltd., the company known as the Guest Keen Baldwins Iron and Steel Co., Ltd., was formed, bringing into one concern the works at Dowlais, Port Talbot, and Cardiff. As a result of this amalgamation the manufacture of such products as rails, plates, and sections was concentrated at Port Talbot, and as the site at Cardiff was considered particularly suitable for a steel works producing sheet bars and billets, it was decided to construct an entirely new plant, of which the original Cardiff blast-furnaces would form part.

The new plant came into production at the commencement of 1936. Considerable ingenuity has been exercised in laying out a plant capable of an output of 500,000 tons of steel per annum within what can only be regarded as a restricted area. Guest, Keen and Nettlefolds, Ltd., have also laid down, on an adjoining site, a new works for the production of wire rod, strip and other small products, the raw material for which, in the form of billets, is drawn from the heavy steel works side of the boundary. The iron and steel works plant incorporates the latest practice throughout, and includes many fine engineering features.

The main mill plant comprises a 40-in. × 8 ft. blooming mill, arranged in tandem with a six-stand continuous billet and sheet bar mill, and a broadside transfer between for serving blooms to a 21-in. three-high mill producing small sectional material. The construction is novel to Great Britain in that an ingot weighing 3 tons can be rolled direct, without cutting or re-heating, into a single length of small billet or light-weight sheet bar, either product being automatically cut to predetermined multiple lengths on leaving the last roll stand of the continuous mill, discard material being, in consequence, reduced to an absolute minimum. The continuous mill is equipped with the new flood-lubricated sleeve bearings which are showing such sensational results as regards power saving, increased mill capacity and bearing endurance, and which indicate practically no deterioration after almost two and a half years' operation.

A recent engineering development at these works has been the equipment of the blooming mill with fabric water-lubricated bearings which are showing a saving of 15% of power compared with the bronze bearings formerly used, and completely eliminate previous expensive lubricants.

The plant generally has a pig-iron capacity of approximately 500,000 tons per annum, and the recent installation of two additional melting furnaces has increased the output of steel to a similar figure. In a general sense, the works is electrically operated throughout and is fortunately located for service from the Central Electricity Board's grid system.

The group of small mills owned and managed by Guest, Keen and Nettlefolds, Ltd., has been developed for the purpose of producing, under more favourable conditions, the manufactures formerly associated with their Rogerstone Works, and are the direct outcome of investigation as to the possible economies to be realised from centralisation on a new site, advantageously situated in relation to supplies of raw material. The plant comprises the following principal units: A continuous wire rod mill; a wire-drawing plant; a chilled-rod equipment; an "Isteg" concrete-bar plant; a nail factory; a semi-continuous merchant bar and strip mill; and also cold-rolling mills. All of these units of plant are of modern type, and are designed for great production.

Still another development of profound local and national significance is the new works now being laid down at Ebbw Vale, where the manufacture of iron, and later steel, has been carried on since the year 1780. In 1936 these interests, comprising the existing iron and steel works, covering a site 2½ miles long by ¾ mile wide, five collieries and an iron-ore field in Northamptonshire, were acquired by Richard Thomas and Co., Ltd., who, with full regard to the welfare of a local population already adapted to iron and steel works conditions, immediately proceeded with the large-scale development of available resources, which include close location of coal and limestone, an advantageous railway system near to a seaport, and adequate water supply.

The new plant includes additional coke-ovens which will increase the total capacity to 1,500 tons of coke per day. Two blast-furnaces (with electrostatic gas-cleaning plant), each of a capacity of 3,500 tons of pig iron per week, have been completely reconstructed with provision for a future third furnace. The new boiler plant has a total capacity of 300,000 lb. per hour at a pressure of 350 lb. per sq. in., in addition to the existing boiler battery of a total capacity of 440,000 lb. per hour at a pressure of 160 lb. per sq. in. The steel plant, to produce 9,000 tons of ingots per week, comprises three open-hearth furnaces, with space for a fourth, and four Bessemer converters and two mixers, the combination allowing of steel for various products being produced by open-hearth, duplex, or Bessemer process, with extreme flexibility and low operating costs.

The type of hot- and cold-rolling mill plant installed marks a complete departure from all methods of sheet production previously used in Great Britain, and incorporates the continuous process of wide strip sheet manufacture which, with many other obvious advantages, entirely eliminates sheet-bar as an intermediate product. The mill plant can deal with 750,000 tons of ingots per annum, and comprises a reversing slabbing mill which reduces ingots up to 10 tons in weight into slabs of any desired thickness and up to 52 in. maximum width, which, after cropping and shearing to multiple lengths, are delivered direct, or through re-heating furnaces, to the continuous hot strip mill, which comprises 11 stands of rolls arranged in tandem.

Auxiliary plant comprises equipment for processing the hot strip into various commercial products, an automatic doubler for preparing the hot-rolled strip for further rolling on hand mills, tempering mills for final preparation of hot-rolled sheet surfaces, continuous normalising and annealing furnaces for heat-treatment, pickling equipment, etc., and all necessary facilities for rail and road despatch. The roll necks of the continuous mill throughout are equipped

(*Continued from page* 102)

Some Fundamental Factors Regarding the Stress-Strain Diagram for Mild Steel

By G. Welter and S. Gockowski

In addition to the series of tests described in the last issue the authors have re-examined the effect of eccentric loading on test-pieces subjected to tensile test and its influence upon the upper and lower yield point. The results of these further tests are given together with those carried out with newly-designed hydraulic-pneumatic equipment,[1] which has been adopted for three different load stages for use under high loads, and with test-pieces of greater diameter.

As a result of a series of tests described in the last issue of this journal, it was shown that the drop in stress at the yield point of mild steel is due to the reaction of the indicating grip holder upon the indicated load, and that a number of tensile testing machines in use do not record this stress drop. It was suggested that a true stress-strain diagram is only possible on soft-sprung machines. A continuation of the work has been carried out under eccentric loading, and it is the purpose of this article to describe these tests and their influence upon the formation of the upper and lower yield point; the stress-strain diagram with and without hydraulic-pneumatic appliances under high loads are also discussed.

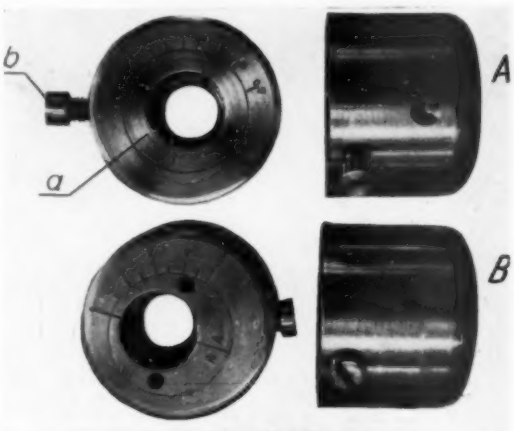


Fig. 1.—Grip holders for eccentrically-adjustable loads. A, eccentricity 0.1 to 0.8mm.; B, eccentricity 0.5–4mm.

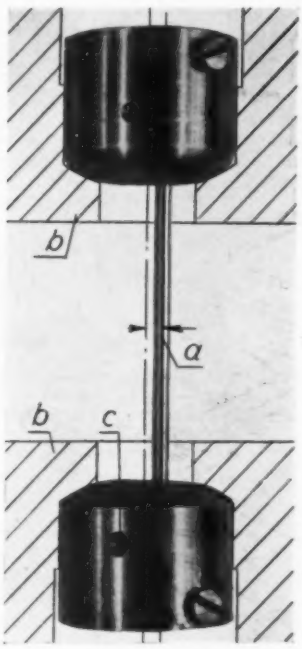


Fig. 2.—Eccentrically fitted specimen.
a, distance of test-bars from centre of force applied.
b, grip-holders of the machine (diagrammatic)
c, recess for fixing the eccentric ring holders.

Influence of Eccentric Loading of Test-pieces on the Yield Limit

Based on the assumption of an appreciable excess of force in the drop from the upper to the lower yield point, the opinion is voiced by various workers (Pomp, Krisch, Siebel, Schwaiger), that in the absence of the upper yield point due to eccentric loading and to the additional bending strain thereby caused, the test gradually begins to yield at the lower limit. As this view should not be turned down off-hand, and since, as was shown in detail at the time by one of the authors, centric loading is of paramount importance when determining the elastic limit in the tensile test[2], the influence of the eccentric loading of mild-steel tests upon the formation of the stress-strain diagram within the range of the yield limit, was subjected to closer examination.

Two pairs of clamping chucks were made for eccentricities up to approximately 0·8mm. (A, Fig. 1), and up to 4mm. (B, Fig. 1). According to the setting of the ring *a* inserted eccentrically test-pieces were checked in this way with eccentric loading rising from 0·1mm. to 0·5mm. by stages of 0·1mm. and from 1mm. to 2mm. The screw *b* secured the eccentrically-supported ring in its position within the chuck, while the latter, in turn, was seated fitting without slackness in a special clamping head of the machine (Fig. 2). Three different test series were carried out with test pieces of 4mm., 6mm., and 8mm. with mild steel, the results of which are reproduced in Fig. 14, A-C. The test speed was in all cases approximately 0·7mm. per sec. (motor drive of machine at maximum loading speed).

The diagrams in the yield range of the limit are very distinct with respect to upper and lower drop and, due to the inertia effect of the pendulum dynamometer of the five-ton Amsler machine, they display severe disturbances in the track of the yield limit. It is evident from the first test-pieces which were carried out with mild-steel tests of 4mm. diameter under eccentric loads between 0mm. and 2mm., according to Fig. 3A, that no fundamental difference occurs in the course of the yield limit. With tests of 6mm. and 8mm. diameter (Fig. 3 B and C) likewise no appreciable difference is to be noted in the formation of the yield limit with eccentric clamping up to approximately 1mm. With an eccentricity of 1mm. and 2mm. for test-pieces of 6mm. diameter and of 2mm. for test-pieces of 8mm. diameter the load jumps in the yield range of the material are less distinctly marked, yet they still permit of clearly discerning the erratic indication of the dynamometer.

On the basis of these tests it would appear that, with such plastic material as mild steel, eccentric application of the load upon the test-pieces remains without proved influence upon the formation of the yield point, with the characteristic superelevations and drops in the load in the yield range. If anything, there appears to be a tendency for a slight reduction of the load to occur as eccentricity at which the upper yield point appears, although this cannot be proven with certainty on the basis of these test-series. Also, in point of breaking strain and elongation* it would appear with the eccentric loadings selected and with this highly plastic material that each eccentric

1 G. Welter and S. Gockowski—*Wiadomosci Inst. Mat.* Rok. 4, No. 3-4.
2 G. Welter, Zeitschr. f. Flugtechnik und Motoriuftschiffahrt, 16, 1927.

* The irregular deviations present in the diagrams with respect to maximum load, elongation, and so forth are likely to be due to minor differences in the dimensions of the test bar, or irregularities in the material.

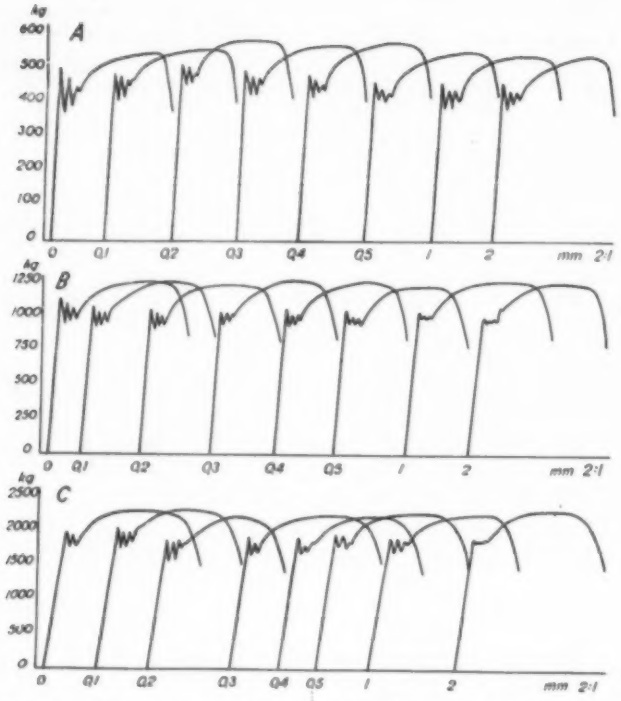


Fig. 3.—Stress-strain diagram of mild-steel subject to eccentric loading.
A, specimens of 4mm. diameter ; B, specimens of 6mm. diameter ; C, specimens of 8mm. diameter. The figures entered in the dagrams denote eccentricity in mm.

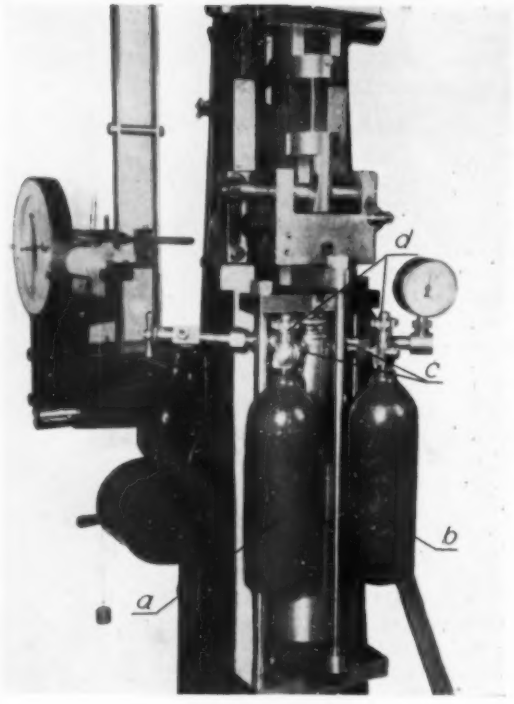


Fig. 4.—Hydraulic-pneumatic appliance with increased gas volume.
a, b, additional steel cylinders.
c, d, control valve and connecting tube.

application of the force is automatically compensated without exerting any appreciable influence upon the results. In a few bending tests (extreme case of eccentric loading), where one fibre of the test-bar is stretched, and the other compressed, a drop from an upper to a lower yield point could also be ascertained in the diagram for soft steel.

Stress-Strain Diagram with and without Hydraulic-Pneumatic Appliances under High Loads.

Tests with the hydraulic-pneumatic appliance to enhance the natural resilience of the tensile machine were further continued, after the equipment had been adapted by increasing the gas volume for higher load stages and, therefore, for testing bars of greater diameter. Up to the present, test-pieces of 4·4mm. diameter maximum can be tested successfully with this appliance. After having increased the gas volume by adding two compression cylinders *a b* according to Fig. 4 (from 1,290 cu. cm. to approximately 4,490 cu. cm.), tests of 6mm., 7·5mm. and 9mm. could be examined by using either one or both flasks, and according to the load range chosen.

The springing of the appliance in high-load ranges of 1,000 to 2,000 kilos was still adequate to obviate reaction of the elongation of the tests upon the load reading in the tensile test. For the tests of 6mm

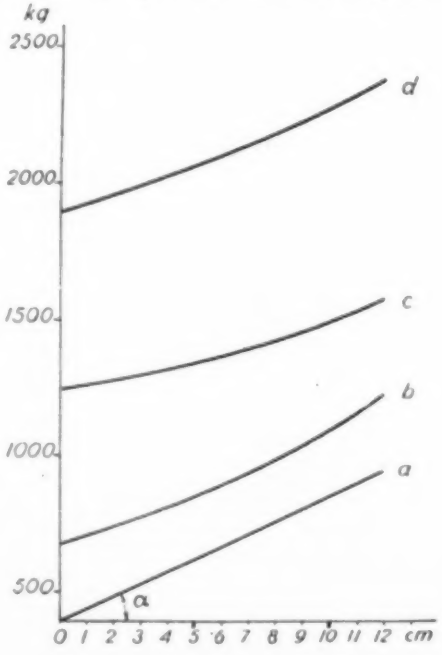


Fig. 5.—Function of spring characteristics of the hydraulic-pneumatic equipment under various internal pressures.
a, helical spring.
b, appliance with 2,890 cu. cm. gas volume, compression nine atmospheres.
c, gas volume 4,490 cu. cm. ; compression 16 atmospheres.
d, gas colume 4,490 cu. cm. ; compression 25 atmospheres.

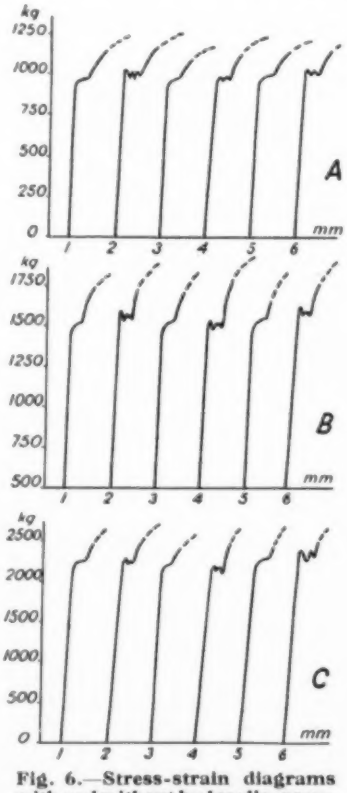


Fig. 6.—Stress-strain diagrams with and without hydraulic-pneumatic appliance. A, diameter 6mm ; B, diameter 7.5mm. ; C, diameter 9mm.

diameter agas volume of 2,890 cu. cm. with an initial internal pressure of nine atmospheres was chosen, whereas for the tests of 7·5mm. and 9mm diameter a gas volume of 4,490 cu. cm. was needed under 16 and 25 atmospheres initial pressure, respectively. In Fig. 5 are reproduced the resilience characteristics of the appliance (load as a function of the spring deflection) in comparison with the helical spring which gave a spring motion of 23mm. against 100 kilos. of load (*a*, Fig. 5). As will be evident from this illustration, the slope of the spring characteristics of the load cases *b-d* is approximately equal to the gradient alpha of the helical spring *a*. With a given pressure and gas volume the appliance may be used in load stages of approximately 1,000, 1,500 and 2,000 kilos. in a loading range of approximately 300 to 500 kilos, for which the springing will still be adequatel ysoft.

The stress-strain diagrams of mild steel obtained with this equipment on the five-ton Amsler tensile machine are reproduced in comparison with those with lock appliance (cotter lock). For each test-bar thickness a diagram was taken with the appliance in order and immediately after the following diagram under the same test conditions, but with cottered appliance, that is to say, with the rigid machine.

In Fig. 6 A are reproduced the diagrams for 6mm. thick test-pieces up to a load beyond the yield limit, the diagrams Nos. 1, 3 and 5 being recorded by the machine with the appliance in operation, and Nos. 2, 4 and 6 with the appliance cut out. The effect of the hydraulic-pneumatic equipment upon the formation of the yield limit is perfectly manifest. The characteristic steady flux in the yield range is invariably recorded with gradual, accurate transition from the straight into a rising branch, without noticeable disturbances due to load drop from an upper to a lower yield point. The yield limit of these test-pieces occurs under approximately 1,000 kilos of loading. Similar results were obtained from stout test-pieces as per Fig. 6, B, C, the yield limits of which for the tests of 7·5mm. diameter lay at approximately 1,500 kilos, and for those of 9mm. diameter at approximately 2,000 kilos of load.

These tests likewise display unambiguously and regularly the effect of soft machine resilience upon the stress-strain diagram at the yield limit—viz., on stout steel tests under loads up to 2,000 kilos. These results thus likewise permit of concluding that a drop in load in hard-sprung machines is not to be ascribed to a peculiar feature of the material, but is contingent directly upon the resilience of the machine.

Conclusions

The results of the tests previously given confirm the view that the springing of the testing machines has a definite influence on the formation of the stress-strain diagram. The load drop on the yield limit in the tensile test of mild steel is a phenomenon associated with the design of the machine used, and cannot be connected with any particular feature of the material contingent on the actual processes within the steel. The further tests, the results of which are described in the foregoing, have been carried out on the assumption, not corroborated by any tests, that it would be possible to determine an upper yield point of mild steel subject only to adequately centric loading will not hold. Eccentric loading up to 1mm. did not show that this form of loading influenced the upper or lower yield point in the test results before us. Consequently, eccentric loading is not of deleterious influence upon the formation of the upper yield limit to such extent as is frequently assumed, or even at variance with the common tensile tests in which the upper yield point appears almost invariably.

The fact that the upper yield point is absent not only on mechanically-sprung machines, but that the same effect is determined equally with hydraulic-pneumatic springing, and this not only with slender test specimens, but also with test-bars of substantial diameter broken at high load stages, should further vouch for the accuracy of our view that the stress-strain diagrams of mild steel obtained on the usual machines in normal use, especially in the range of the yield limit and the breaking-point of specimens do not conform to actual conditions.

Ferrous Metallurgy in Soviet Russia

By a Special Correspondent

ALL ferrous metallurgy in pre-revolutionary Russia was concentrated in the central industrial region, in the Urals, and in different districts of East Siberia, and the production of steel, including high quality steel for the needs of the army and navy, was centred only in the works at St. Petersburg and its environs. In these regions was produced one-fourth of the entire output of pig-iron in the Russian Empire, the remaining three-fourths being turned out by the Ukraine.

The production of steel on the territory now constituting Soviet Russia was more developed, the output falling mainly to the central region, the proportion produced in the Ukraine being somewhat less than two-thirds of the total output. The production of pig-iron and steel in 1913 is shown by the following figures (in tons) :—

Central Region		Urals and Siberia	
Pig Iron	Steel	Pig Iron	Steel
195,100	611,800	913,400	906,600

After the establishment of the Soviet regime the position was considerably changed, as may be seen from the figures of production for 1936 (in tons) :—

Central Region		Urals and Siberia	
Pig Iron	Steel	Pig Iron	Steel
1,126,100	2,562,900	3,961,500	4,792,200

During the 14 years of expansion of pig-iron and steel production (counting from 1923, when it first became possible to supply the works with all the requisites for production), the output of pig-iron in the central region had increased nearly sixfold, and in the Urals and Siberia somewhat more than fourfold, while the production of steel in the central region (including Leningrad) had increased fourfold, and in the Urals and Siberia more than fivefold. The Ukraine produced a little less than two-thirds (64%) of the total output of pig-iron, and a little more than half (54%) of the total output of steel in the Soviet Union.

Blast Furnaces

This progress was made possible by the building of the Kuznetsk and Magnitogorsk Works and the creation of a new base for the ferrous metallurgical industry. Despite the stopping of many charcoal furnaces at the Vyksa, Kulebaki and the former Maltsev Works, the production of pig-iron in the central region, as compared with pre-war times, was considerably increased. This was due to the building of powerful blast-furnaces in Lipetsk and Tula. Out of the first 14 furnaces, each of 930 cubic metres volume, built in the Soviet Union, four were in the central region. Two of these furnaces now each supply an average of about 800 tons of pig-iron a day, from Lipetsk ores, and the other two, each about 725 tons a day, from the poorer Tula ores.

Notwithstanding the stoppage of many charcoal furnaces in the Urals, the production of pig-iron there was also considerably increased, thanks to the starting of the four

Magnitogorsk furnaces, which until lately, were the most powerful furnaces in the Union. In 1936 these furnaces each produced on an average 1,200 tons a day. However, this was not the limit of their capacity as frequently the output of pig-iron per furnace at Magnitogorsk reached 1,500 tons a day.

The four furnaces of the Kuznetsk Works are working no less efficiently. In the aggregate they produce rather less pig-iron than the Magnitogorsk furnaces, because the first two of them are of smaller volume (828 cubic metres). However, the productivity of these furnaces on the whole is higher than all the furnaces in the Urals, with the exception, of course, of those of Magnitogorsk. In regard to the charcoal furnaces, out of 36 of them in existence, only fifteen are usually working, but their productivity, as a result of more efficient operation, has much increased as compared with former times, and frequently reaches 150 tons a day per furnace. With the present method of operation, the time that the ore remains in the furnace has been reduced to 4½ and sometimes to 4 hours, while the utilisation of volume, expressed in cubic metres per ton of daily productivity, is the same as in furnaces working on coke, where the charge remains in the furnace 8 to 7½ hours.

In 1936, the co-efficient of utilisation of Soviet blast furnaces working on coke averaged 1·08, having been reduced 1½ times as compared with pre-war days.

The development of the Stakhanov movement at the metallurgical works was of immense help to the more efficient utilisation of the volume of blast furnaces in 1936; during the course of that year, the co-efficient of utilisation of the volume of blast furnaces working on coke was reduced from 1·2 to 1·08.

Steel Production

The development of steel production, as compared with pig-iron production, took place somewhat later, but the progress made has been equally good. The increase in the output of steel in the Soviet Union was made possible by the building of powerful open-hearth melting shops at the Magnitogorsk and Kuznetsk Works. At these works were built 24 open-hearth furnaces with a hearth area of 66·58 sq. metres and a designed capacity of 150 tons each. One of the furnaces built at the Kuznetsk Works, has a hearth area of 73·4 sq. metres and is designed to make batches of 300 tons.

The first furnaces at these two latter works commenced to work with batches of 150 tons. The discharge of steel per sq. metre of hearth was at first no higher than in the good furnaces of the old works (about three tons). This was due to the fact that the operators had had to learn how to use the new highly perfected equipment, but when they had become familiar with it, they had recourse to the old method of increasing the productivity of furnaces, that is to say, they worked at "over load," increasing the depth of baths and using batches of 200 tons and more to the same area of hearth. By augmenting the supply of gas and air to the furnaces and increasing their thermal power, the discharge of steel per sq. metre of hearth was gradually raised. During 1936 the average discharge at the Kuznetsk Works was 4·69 tons and at the Magnitogorsk Works 4·84 tons per sq. metre of hearth. The two works together in 1936 produced nearly 2,409,400 tons of steel in ingots, that is, half as much as was turned out by the rest of Siberia and the Urals.

The other open-hearth furnaces in the Urals, the central region and Leningrad, being of lesser capacity, give a smaller discharge of steel per sq. metre of hearth. This is due not only to the fact that these furnaces are of less up-to-date construction and lower degree of mechanisation, but that many of them have to produce higher quality steel (the works at Zlatoust, Perm and Leningrad). The discharge of steel from these furnaces varies from 3½ to 4 tons per sq. metre of hearth. An exception are the open-hearth furnaces at the Moscow Hammer and Sickle Works, where the discharge averages 5·74 tons per sq. metre of hearth.

Some Recent Developments in the Iron and Steel Industry in Britain

(*Continued from page* 98)

with roller bearings, lubricated from a pressure oil system with continuous circulation through oil coolers and cleaners. Before further reduction by cold working, coiled strip is transported by conveyers to the continuous pickling department and delivered thence over gravity conveyers either to the sheet or tinplate departments, where the coiled strip may be passed through three mill stands in tandem for reduction to finished sheet gauges in widths from 20 to 50 inches in the first case, or through five stands of rolls in tandem for producing tinplate material from 12 in. to 36 in. wide.

Northamptonshire

The opening up of this part of the country as a centre of large-scale iron and steel production is of profound importance to Great Britain, inasmuch as the development is principally due to the reintroduction, under favourable conditions, of basic Bessemer steel manufacture, for which the Northamptonshire ores are well suited. These extensive ironstone deposits have been mined on a relatively small scale for many years, but it was not until 1932 that Stewarts and Lloyds, Ltd., decided to embark on large-scale developments with the installation of a complete new works, designed for an output of 600,000 tons of steel per annum.

This plant is now in full operation, and embodies not only every essential feature of a thoroughly modern iron and steel works, but also incorporates many special features of particular interest to the engineer. The rolling-mill plant comprises a massive 40-in. reversing blooming mill, an intermediate 32-in. reversing mill, followed by a continuous 24-in. billet mill and a two-stand tandem mill, also two strip mills, both of the continuous type for producing strip material as required for tube manufacture, or any other purpose. The larger of these mills has a capacity of 220,000 tons per annum of strip from 2½ in. to 23 in. wide, and the product can be delivered in coils or straight sheared lengths, in accordance with requirements. The smaller mill produces strip from 1½ in. to 8 in. wide, and has a capacity of approximately 150,000 tons per annum. The continuous billet mill, which as a normal product produces billets down to 2½ in. square, also rolls rounds or slabs, the latter for serving the strip mill.

Coils from both strip mills, after cooling and inspection, are transferred to the tube works, where they are manufactured into tubes by the Fretz-Moon continuous welding system. The process is characterised by continuous welding of the strip as unwound from the coil and passed through the leveller, the end-trimming shear, and the flash-welder for joining ends of successive coils, to the heating furnace, and thence direct to the welding roll train.

A push-bench plant produces seamless tubes from square steel billets by piercing and drawing processes, the finished product ranging from 2½ in. to 4 in. nominal bore, smaller sizes down to ¾-in. nominal bore being obtained by further working through a reducing mill of special type. The output of seamless tubes is 50,000 tube tons per annum.

Conclusion

This review could in no sense be considered complete without reference to the important extensions to plant which have been made, or are in progress, in North Wales, Lancashire, the Sheffield area, Lincolnshire, the North-East Coast of England, and Cumberland, but space limitations will not allow of detailed reference to such developments. In the area first mentioned a fundamental change in practice at a leading works will result from the installation of a modern continuous hot-strip sheet rolling mill, and many of the other schemes referred to are of an order approaching the status of separate works.

Recent Developments in Materials, Tools and Equipment

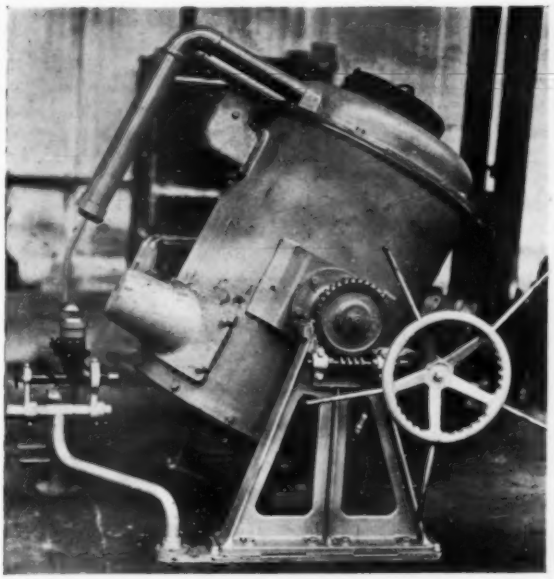
New Tilting Melting Furnace

FOR a number of years crucible tilting furnaces have been proved very suitable for melting non-ferrous metals and alloys, and several designs are in regular use. Whether fired with town's gas or oil they are more efficient than many types of furnaces used for non-ferrous work. It is noteworthy therefore, that further efforts to obtain higher efficiency in fuel consumption have resulted in new design which makes use of superheated air. This tilting furnace, which incorporates Hall's patents, is manufactured by Monometer Manufacturing Co. Ltd. Combined with high efficiency in fuel consumption, it occupies minimum floor space, whether installed as a single unit or in batteries, it is easy to operate and facilities are provided for access to all parts.

As will be noted in the accompanying sectional elevation of this new furnace, the design for the main structure corresponds to that with which many readers are now familiar, but the chamber is sealed to prevent the possibility of contact between the gases from combustion and the metal, at the same time the hot gases are used to heat the air supplied to the furnace with the fuel.

The body C, cylindrical in form, is of heavy mild steel plate; the base plate D also is of mild steel and without ribs to facilitate cleaning; the preheated air supply is through the mild-steel pipe E. Two steel preheated tubes are fitted to the main body and are detachable, resting on spherical joints as at V. The pressure air enters at X, passes up pipe and round a cored space F in the main cover, absorbing heat from the furnace on its flow through the chamber, then passes to the burner G. The body cover is of high quality hæmatite cast iron, secured to the body by hinged bolts. The flue J is lined with high grade refractory and is fitted with a controlling damper. The operating gear for tilting is of the self-sustaining roller bearing and worm system, so that pouring can be controlled with the greatest ease and accuracy and can be arranged for lip or central-axis pouring.

The furnace chamber may be ram- or brick-lined to suit the particular melting conditions. The former method has this advantage that the chamber may be relined by unskilled labour, producing a thoroughly homogeneous surface without joints and dispensing with specially shaped brickwork. The crucible, made of graphite, steel or tantalum iron, is provided with a muffle ring so that the furnace



One of the small capacity furnaces of this type in operation.

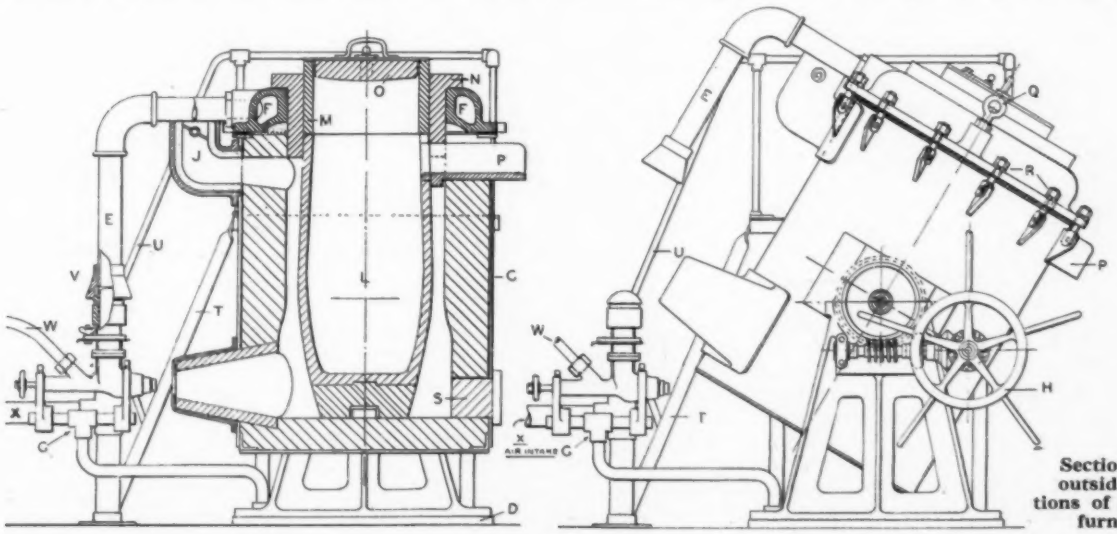
can be fully charged at the outset. The fuel, which may be town's gas, oil or pulverised coal, enters the burner through the pipe L.

The furnace is constructed in three sizes for the following capacities :—

	Lb.		Lb.
Aluminium	500/600	Brass	1,500/2,000
,, ...	300	,, ...	1,000
,, ...	150	,, ...	500

The larger size furnaces are fitted with charging platform, ladder T and handrail U, and the bodies for each size are interchangeable to avoid any stoppage for relining.

Among the several advantages claimed for this new melting furnace are: it entirely eliminates contamination of the metal with gases being used for melting purposes. The spent gases are taken away adjacent to the top of the furnace, midway between the crucible and the auxiliary muffle ring used, the latter producing a sealed joint. A



Sectional and outside elevations of the new furnace.

further advantage is the superheated air supplied to the furnace, which enters round the dome of the furnace and passes to the burner. This not only ensures more rapid and efficient melting, without chilling effect on the crucible, but also reduces fuel consumption considerably and facilitates the complete atomisation of the oil, gas or pulverised fuel being used.

Self-lubricating Bearings

A GREAT advance in the whole field of power transmission, alike as regards efficiency and convenience, is the " Oilite " self-lubricating bronze bearing, a production of the Manganese Bronze and Brass Co. Ltd., which in most cases will run for years without oil or grease. The metal has the usual composition of high grade bronze, 89–90% copper and 10–11% tin, but because of the use of special processes of manufacture it is micro-cellular in structure and all the interconnecting cells are charged with high-grade lubricating oil, which amounts to about 25–40% by volume of the total bearing.

This oil forms a permanent film at the surface of the metal and is also exuded to an increased extent according to the pressure or heat applied. Consequently the bearing gives continuous lubrication to a degree of efficiency impossible to obtain by the conventional solid bearings with added lubricant, because the film is always absolutely uniform. Also the strength of these self-lubricating bearings is almost identical with that of the solid metal and they will stand easily 4,000 lb. per sq. in. pressure, far greater than necessary in nearly all industrial drives. For heavy duty service supplementary lubrication can be added from a reservoir arranged in the supporting housing of the bearing. Because of the lubrication efficiency the running is absolutely noiseless, while all the troubles with oil spillage are eliminated.

These bearings also in general cost no more than the ordinary type, while a large number of standard sizes' nearly 200, all made to very fine limits, are available within the range of $\frac{1}{8}$ in. to $2\frac{1}{2}$ in. bore, all ready for direct use without machining or other adjustment, and the provision of oil holes or grooves is not essential.

The actual amount of oil required to maintain a permanent film in a bearing for say 500,000,000–750,000,000 revolutions, a considerable number of years, is extraordinarily small and in this connection elaborate tests have been carried out with " Oilite " bearings. For example, one test was a long duration continuous run of 264,500,000 revolutions, taking 4010 hours, about 500 working shifts, using a bush $1\frac{1}{4}$ in. long, $1\frac{3}{8}$ in. diameter, and $1\frac{1}{4}$ in. bore running at 1,100 r.p.m. and 60 lb. per sq. in. pressure, under temperature conditions 120°F. (48·9° C). At the commencement of this long run the oil content of the metal was 35·19% and at the finish 23·38%, while the total wear on the bearing was only 0·0012 in.

Another test on a bearing 1 in. long, 1 in. diameter, and $\frac{3}{4}$ in. bore running at 2,000 r.p.m., 80 lb. per sq. in. pressure and 71° F. (21·8° C.) for 30,000,000 revolutions (250 hours) showed a reduction in oil content from 29·43% to 26·37% with 0·0002 in. wear on the bush. Very high speed conditions give the same general result, and for example, a bearing 0·659 in. long, $\frac{11}{16}$ in. diameter, and 0·355 in. bore running at 9,500 r.p.m. in a vacuum cleaner for 456,000,000 revolutions (250 hours) at 46° F. (8° C.) was reduced in oil content from 36·9 % to 31·0% with a wear of 0·0004 in. on the bearing.

Novel Device Collects Deadly Lead Dusts

THE midget impinger, a novel air-dust collecting device developed by the Bureau of Mines, Department of the Interior, as an aid in the fight being waged against the widespread industrial menace of breathing harmful dusts, has been found to be specially efficient in the collection of the deadly lead dusts. The results of tests made to determine the efficiency of the impinger for collecting lead dusts and fumes are summarised in a report recently published by the Bureau.

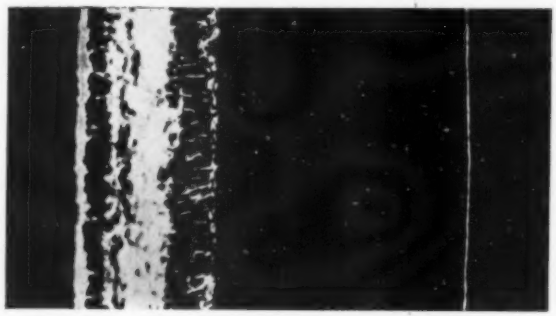
This instrument gives results comparable to those of the large impinger for collecting pneumoconiosis-producing dusts from the air. The midget impinger is lightweight, compact, readily portable, and is much more easily used than the large impinger. In the development work the midget impinger was tested against pneumoconiosis-producing dusts only, although it was known that there was possibility of wide application. Because of its many advantages, further tests have been conducted to ascertain its practicability for collecting lead dust and fume for chemical determination. The results of these tests showed that the efficiency of the midget was essentially the same as that of the large impinger, and that each impinger had a collecting efficiency that compared favourably with that of the electric precipitator, which is the most efficient instrument available for collecting atmospheric particulate matter.

Although both the large and midget impingers were shown to have a satisfactory collecting efficiency for lead dust, neither had been tested for its efficiency against lead fume. Lead fume is generated by heating or volatilising lead or burning volatile lead compounds. The particles thus formed are much smaller than the mechanically generated lead dust usually found in industry. Owing to their small size, it would be expected that they would be more difficult to collect. The results of tests showed that the efficiency of the large and midget impingers for collecting lead fume was very low and varied greatly when compared to the electric precipitator. Under the usual operating conditions, therefore, the impingers are unsatisfactory for collecting lead fume.

Copies of Report of Investigations 3401, " Efficiency of Impingers for Collecting Lead Dusts and Fumes," by J. B. Littlefield, Florence L. Feicht and H. H. Schrenk, may be obtained from the Bureau of Mines, Washington, D.C.

Fine Aluminium Wire

What is probably the smallest and lightest exhibit at the Glasgow Empire Exhibition is an aluminium wire so fine that 10,000 pieces laid side by side would measure only one inch in width. This phenomenal exhibit weighs 0·000000009246 lb. per ft. and has a diameter of $\frac{1}{10,000}$th of an inch. 600 of these aluminium wires will be equivalent to the thickness of one human hair. Invisible to the naked eye, this amazing exhibit can be seen through a high-powered microscope on the stand of Aluminium Union Limited in the Canadian Pavilion.



Human hair. Aluminium wire.
Micro-photographs comparing the diameter of human hair with the diameter of aluminium wire which is exhibited in the Canadian Pavilion at Glasgow.

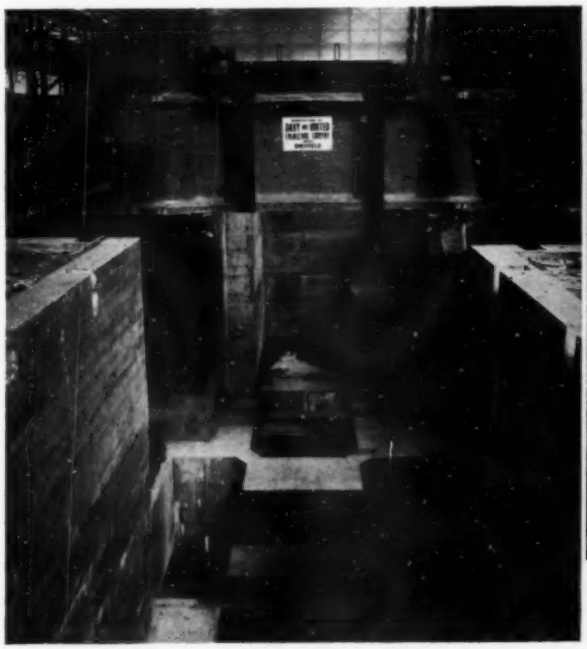
Fine aluminium wires are used in seismic prospecting, a modern method of finding oil by means of sound detection. on similar lines as a sound detector is used by the Navy to establish the presence of submarines. The difference in vibration caused by detonation in the earth is recorded by these fine aluminium wires in a galvanometer.

Weldless Steel Forgings

Important Extensions by Chesterfield Tube Co.

New shops recently erected are being equipped with heavy tube-making plant capable of dealing with the manufacture of hollow steel forgings and pressure vessels up to 52-in diameter.

THE recurring demands for all kinds of hollow forgings of increasing sizes and weights, and the constantly increasing use of gases, air and steam under high pressures for Government and commercial purposes have caused the Chesterfield Tube Co., Ltd., to carry out developments to meet these demands. With this object, it was decided to adopt a scheme of layout to increase considerably the company's existing extensive range of products. As was noted in the previous issue of this journal, the new shops have been completed, and the installation of plant and equipment is in progress which will enable the making of heavy tube of a size and weight exceeding any other of a like nature operating in the world at the present time.



The 85-ton cast steel base plate of the billet piercing press being lowered into position.

The new plant is designed for the manufacture of pierced and drawn weldless tube of a size and weight hitherto unobtainable by the same process. The manufacturing range will comprise as standards weldless tube up to 40 in. outside diameter, with a maximum length of 35 ft. and also specials up to 52 in. diameter. The maximum billet or ingot weight to be operated will be approximately 20 tons, and the weight of the finished product approximately 16 tons. The plant will consist of a vertical hydraulic billet-piercing press of the triple cylinder type construction. Auxiliary hydraulic cylinders are fitted for moving the container from under the press and ejecting the pierced blooms. The press is of exceptional size, and has a total weight of approximately 850 tons. It is capable of producing a hollow forging 9 ft. long in one operation.

The horizontal drawbench is also of the triple cylinder type and hydraulically operated. The maximum stroke is 40 ft., and hollow blooms of about 20 tons weight can be mandrel-drawn. The drawbench has an overall length of 146 ft., and weighs about 510 tons. The furnace arrangements comprise a bogie tunnel furnace of the multi-pass regenerative type, with a temperature variation of 900° C. to 1,300° C., a soaking pit furnace of the multi-pass regenerative type designed for a maximum working temperature of 1,500° C., and a tube reheating furnace of the recuperative type. These furnaces are fired by gas transported through pipes from the coke-ovens of local collieries.

Additional Equipment

The equipment includes a 50-ton crane fitted with duplex hoists, a 20-ton guided type crane, a 20-ton general purpose crane, and a 12-ton crane with two separate 6-ton crabs. Included in the new machine tools are lathes of 30-in centres, 33 ft. and 45 ft. between centres, respectively, driven by 75 h.p. motors, and a vertical turning and boring mill capable of boring production tools up to and including 84 in. by 3 ft. long; this will be driven by 25 h.p. and 7·5 h.p. motors running at 900 and 1,000 revolutions respectively, the table speed being 1·58 to 34·55 r.p.m.

View of new shops showing horizontal hydraulically operated tube draw bench and other equipment in course of erection.

Main Plant Power

High- and low-tension electrical switch-gear will be provided and D.C. power will be transformed to suitable voltages for the various equipment. The hydraulic power unit for the piercing press and drawbench consists of three pumps, each driven by 600 h.p., 6,600-volt, 3-phase synchronous motors. The accumulator is of the air hydraulic type, consisting of air bottles and water bottles. The pumps are arranged to work continuously when the plant is working, and electrically-operated valves control the supply of pressure water to the accumulator as the demand of the piercer and drawbench lowers the water level.

Applications of Products

These extentions and new plant will permit the manufacture of pierced and drawn weldless steel hollows of

large size and range, and will serve as an exceptional source of supply for a very wide range of products both to the home and export markets. Although the new plant has been laid down mainly with a view to commercial requirements, there is little doubt that it will also be found to be of great value to many Government departments. Weldless steel forgings of the calibre possible with this plant can be applied readily for a considerable number of purposes, of which mention may be made of steam-pipes for high-pressure steam installations; water and steam drums for marine type boilers; high-pressure bottles for the storage of liquefiable and permanent gases; cylinders for CO_2 converters; Diesel engine air-starting bottles; submarine air vessels; superheater headers; mud drums; torpedo body forgings; shell forgings, etc.

This plant is expected to be in operation towards the end of this month.

Studies in Mineral Physics bring Practical Results

STUDIES in the field of mineral physics form the basis for six papers of a somewhat specialised type contained in a progress report just published. It is the third Mineral Physics Report in the Metallurgical Division Progress Report Series.

In the case of metals and metallic minerals it is pointed out that the differences between the poly-crystalline substances and those of single crystals are marked and of great practical importance in metal and ore treatment. The problem discussed in a paper on "Physico-Chemical Nature of Metallic Interfaces," covers the physico-chemical state of the metal atoms at interfaces, which describes how this accounts for the pronounced changes of mechanical, magnetic, and electrical properties that accompany increased internal surface. Two papers describe the construction and operation of coercimeters and a magnetic balance for magnetic measurements that have assisted in the study of the composition and structure of ferromagnetic metals, minerals, and metallurgical slags.

As little work has been done on the variation of coercive force with torsion, experiments were run on certain iron rods and on nickel rods and on nickel-iron rods. The rods were twisted and magnetic measurements were made at the National Bureau of Standards. There was considerable change in coercive force for even small permanent twists in the nickel rods. The results from iron rods were compared favourably with those of another investigator.

A year ago the industrial world became interested in the application of high-pitched sound waves to the settling or dissipation of smoke, fume, and dust. One paper in this report describes the construction and operation, in its present stage of development, of the sonic flocculator. The essential parts are a vibrating body for producing the sound waves and a resonating chamber for producing the sound field. The physics involved in the flocculation of particles is complex and is given in detail. As yet, the sonic flocculator is unproved as an industrial process, but it does open a new field for treating stack effluents and it awaits a means for efficient generation of high-frequency sound waves on a large scale.

Magnetite is the theme of the sixth paper. This mineral may be age-hardened. When formed from hæmatite, it was studied by magnetic means, by X-ray analysis, and by heat treatment. Lower temperatures of reduction increased the coercive force of the resultant reduced hæmatite, and the type of reducing gas also affects the coercive force. The effect of simple stresses on the magnetic properties has been verified by magnetite.

Copies of this Report of Investigations 3400, "Progress Reports—Metallurgical Division. 24 Mineral Physics Studies," may be obtained from the Bureau of Mines, Washington, D.C.

Steel Tube Economisers

FOR efficient steam generation with water-tube boilers the best method is to distribute the heat in the waste gases from the combustion chamber between economisers and air-heaters in the correct proportion. For pressures over 500 lb. per sq. in. it is necessary to use steel tube economisers, which can be operated under "steaming" or "non-steaming" conditions. It should be pointed out, however, that the function of the economiser even when "steaming," is different from the boiler, being concerned with absorbing heat from the combustion gases after the latter have been cooled to a considerable extent, say below 650° F., and under conditions that the water is always travelling in one direction only, with gradual increase in temperature, and without circulating.

The latest scientific methods in this field are well represented by the "Foster" economiser of E. Green and Son Ltd. In basic principle this design consists of a series of horizontal steel tubes, 2 in. internal diameter and up to 30 ft. in length, fitted with a series of outer cast-iron gills, which are shrunk on the steel tubes. The latter are fixed in staggered rows, one above the other, and each tube connects with the one above and below, at alternate ends, by means of a semi-circular forged steel bend. The cast-iron gills, with their enormously enlarged heating surface, increase the heat transmitting properties about six times as compared with plain tubes, while at the same time preventing external corrosion from the acid combustion gases.

All the tubes are contained within an outer steel casing, and the bottom row connects direct to an inlet header of forged steel, circular in cross section, from which the feed water flows upwards through the whole series of horizontal tubes, passing from one to the other in reverse direction by way of the bends.

In the case of the "non-steaming" economiser the water flows out of the top row of tubes to a similar forged steel header which then connects by a single delivery pipe (duplicated if necessary) to the boiler drum. The "steaming" economiser, however, has no upper outlet header, but each row of the top tubes connects direct and separately to the boiler drum by a corresponding row of 2-in. steel pipes, side by side, conveying the mixed steam and water. But if steam should form for a short period in the "non-steaming" economiser there is no harm done, so that operation can be carried out very near the steaming limit, enabling the maximum efficiency to be obtained without danger.

A typical interesting installation of "Foster" non-steaming economiser is operating at the Kirkstall power station in conjunction with a pulverised coal-fired boiler, 490 lb. per sq. in. working pressure, and a normal evaporation of 200,000 lb. of water per hour. The economiser comprises 144 tubes, each 20 ft. 4½ in. long, arranged 12 tubes wide and 12 tubes high, being 8,640 sq. ft. heating surface, fixed high up in the setting, level with the top drums of the boiler, formed in 3 groups of horizontal tubes each of 4 rows high, one above the other, all contained within a steel casing formed as usual of girder framework with hinged panels which can be opened up in a few minutes. The gases from the combustion chamber average 650° F. and after passing through the economiser are reduced to 465° F. whilst the feed water is raised from 300° F. to 359° F. the boiler having not only a superheater, but also a complete installation of water-cooled walls.

METALLURGIST WANTED, possessing first-class qualifications and experience in modern furnace practice. Apply by letter only, stating age and salary required, to Shell-Mex and B.P. Ltd., Fuel Oil Department, Shell-Mex House, London, W.C. 2.

The National Physical Laboratory

To maintain the closest contact and friendly relations between industry and this national research establishment, the work of the latter was reviewed recently by a large number of scientists from all parts of Great Britain, and in this article brief reference is made to some of the exhibits.

THE work of the National Physical Laboratory is concerned primarily with the systematic scientific exploration of new problems with a view to increasing our fundamental knowledge and to enable scientific discoveries to be applied to the benefit of mankind. It has been said that research is essentially exploration for which the investigator has to fashion his own specially sensitive and delicate instruments, and a visit to the various departments of this Laboratory supports this view. The work covers a very wide field, including all branches of physics, electricity, and magnetism, radio communications, engineering, metallurgy and chemistry, aeronautics and ship design in relation to form and propulsion.

The Laboratory comprises eight departments—physics, electricity, radio, metrology, engineering, metallurgy, aerodynamics, and the William Froude Laboratory,—and the work of these departments, especially the advances made during the past year, were reviewed by a large number of scientists from all parts of Great Britain on the occasion of the recent annual inspection by the General Board. The visitors were received in the large hall which houses the million-volt electrical plant, by Sir William Bragg, O.M., president of the Royal Society and chairman of the General Board, Lord Rayleigh, chairman of the Executive Committee, and Dr. W. L. Bragg, director of the Laboratory. Special exhibits demonstrating the work were staged in the departments, and reference is made here to the exhibits in some of these departments.

In recent years considerable attention has been given to the production of pure metals. It is realised that high standards of purity in the production of the elementary metals is of vital importance. Modern metallurgical research has shown conclusively that the removal of impurities to the level that has been achieved in producing such metals as aluminium, copper, zinc, lead and cadmium may appreciably affect their engineering and industrial properties. Refiners are now producing these metals to a standard of 99·99% or over.

Metallurgy Department

Considerable attention has also been given to the production of high-purity iron, and several processes are now in operation. Further progress in this field has been achieved as a result of recent research work in the metallurgy department of the Laboratory. The electrolytic method formerly employed in this department failed to remove traces of certain elements, especially nickel. The new work has resulted in the adoption of a chemical method of preparation. In this method purified ferrous chloride is decomposed by steam at a carefully regulated temperature, and the oxide so formed can be washed free from the chlorides of other metals by means of water. The dry oxide is reduced in hydrogen and is subsequently melted, first under slightly oxidising conditions, then in hydrogen, and finally in vacuo. The melting of the iron without contamination has been made possible by the use of the high-frequency furnace and the production of special refractory material. Pure magnesia has been found most suitable for crucibles for the oxidising, melting, and pure alumina for the final operation. The apparatus and refractories, which have been developed for this work, were exhibited, and also samples of the pure iron prepared.

Much interest was shown in an exhibit covering progress in the work on magnesium alloys, which is being conducted at the Laboratory. An alloy has been developed, in which the alloying element is aluminium, whose physical properties in the forged condition are comparable with the high-strength aluminium alloys. After suitable treatment, this alloy has a maximum strength of 27 tons per sq. in., with an elongation of 6·5%. It is shown that this elongation is increased to 11·5% by the addition of 1·5% of silver to the alloy, while retaining the high strength value.

A new gas-fired furnace was on view which has been installed to enable accurate optical determinations in testing Seger cones and refractory materials. These Seger cones are commonly used in the ceramic industry to determine temperatures and a series of them have softening points so distributed as to form a scale and accurate measurements with an optical pyrometer are necessary to determine the true temperatures corresponding to these softening points. Pure alumina is used in the construction of the new furnace, and the design of the gas burner has been improved so that a temperature of 1,900° C. may be reached without difficulty. Furnaces of similar construction are also used for firing the refractory vessels required for the work of this department.

Of considerable interest was a series of cooling curves of alloy steels. These are automatically determined by a combination of the Rosenhain plotting chronograph, with the automatic potentiometer designed in the metallurgy department. The apparatus, which was exhibited, provides a means for the completely automatic plotting of cooling curves over a wide range of temperatures. Apparatus designed in this department for controlling the change of temperature of a furnace in such a way as to give a strictly linear change over a wide range has also been used in conjunction with the chronograph and potentiometer, and examples of the curves so obtained were shown.

Engineering Department

One of the most interesting exhibits in the engineering department concerned frettage corrosion of closely fitting metal surfaces. For many years engineers have been mystified by a peculiar type of corrosion which is manifest with closely fitting metal surfaces, such as those used in airscrew shafts, hubs of gears, fitting bolts, flanges, etc. It is noticed that the trouble only occurs when vibration is present. The result of this action is that a fine reddish-brown dust—not unlike cocoa—appears between surfaces which are usually regarded as so tightly fitting that no relative movement is possible. With oiled or greased surfaces a reddish sludge oozes out, and when one of the metals is iron or steel it appears as if the metals were bleeding. With accurately fitting surfaces which are frequently taken apart and reassembled, the metals have sometimes become so badly pitted as to render them useless, and renewal of the parts is essential.

This interesting phenomenon, known as "frettage corrosion," because the metal is fretted away, is being studied in detail in the Laboratory. It is found that certain combinations of soft and hard metals, especially when lubricated, appear to reduce the corrosion effect, but so far no combination of surfaces has been found to be immune.

In each department the exhibits showed progress in the advancement of scientific knowledge, much of a fundamental character, but all with a view to their application to the needs of mankind. Apart from work of a fundamental character, the work of the Laboratory is of immense importance to industry, since it is concerned with new problems, which are continually being presented, in

establishing facts which can be applied to industry, and, generally, in facilitating the progress of industry by assisting in providing a fuller knowledge of materials and structures. Its work in the past has proved invaluable, and in view of the work in hand there is every indication that it will continue to be of great service in assisting to maintain the scientific and technical prestige of this country.

Investigations on Steel Strip for Tension Springs

By HERMANN POELLEIN.

THE investigations, carried out in 1929 and 1930, are published after it could be stated that the silico-manganese spring steel, considered the best of the investigated steels, has been introduced into the German industry of watches, gramophones, etc. in a large scale and has stood the test very well. The purpose of the investigations was to determine the conditions for the production of a high-duty tension spring steel. The problem is of greater importance than it would at first sight seem to be, for the demand for such springs could be estimated to 2,000 to 3,000 tons per year for the German industry concerned, at the time of these investigations.

The publication deals at first with preliminary work such as the study of the literature and especially of the methods of testing the spring steel. As existing methods proved inadequate a new possibility of testing had to be developed in order to be able to measure the quality of a spring numerically. This method is described in detail, and so are the necessary apparatus, etc.

Fifteen plain and four alloy steels, prepared by various melting processes, were worked up into springs of uniform dimensions and compared with springs produced from four different Swedish spring steels, imported as ingot in one case, and as strips in the three other cases.

From the results, which are shown in graphical and tabular form, the following conclusions are derived: For some of the investigated steels it was not possible to give the precise reasons why the steel is not suitable for the purpose in question. There are so many variables, which influence the properties of each charge of steel, that two charges, produced in the same furnace under apparently the same conditions and characterised by the same analysis, can give, the one useful, the other useless springs. Such charges, which give, if repeated under apparently equal conditions, sometimes good and sometimes bad results, are naturally very dangerous for the manufacturer; for the failure can be found in many cases only after the spring is finished, or even—if a clear method of testing is not applied or not applicable—only by the customer during use. Therefore, the manufacturer of springs may apply only steels which—in spite of the differences of the individual charges—always give springs responding to the demands. This condition is fulfilled by the Swedish steels for tension springs and that was the reason of their almost exclusive use at the time of these investigations.

Also the steels manufactured in Germany with Swedish raw material gave good results, a proof of the great influence of the raw material used. Moreover, it was possible to have a good result from an electro steel produced from scrap; but in this case a four-hours-long refining, carried out with great care was necessary, reducing the sulphur contents to 0·009%. Very different are the conditions of the silico-manganese steels. The quality of the charge as well as the melting process are not so important; it can be taken for granted that silico-manganese steels of suitable analysis can give high-duty tension springs in any case, provided that special care is taken of usual working conditions during the melting process.

Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf. Volume XIX, issue 18.

Comparative Investigation of Mechanical Properties of Steels under Vibratory Stress

By ANTON POMP and MAX HEMPEL.

TWENTY-ONE steels of different nickel contents were examined in order to find out whether steels with low or without any nickel could be used for parts where, at present, only much more expensive steels of high nickel contents are used.

The steels have been divided into two groups of tensile strengths between 76 and 82 tons/sq. in. and between 57 and 63 tons/sq. in. respectively, both with two subgroups of low and high nickel contents.

Eight different kinds of testing were carried out concerning:—

1. Hardness testing of surface.
2. Hardness testing of section.
3. Tensile strength testing.
4. Notch impact testing.
5. Fatigue bend testing.
6. Fatigue tortion testing.
7. Alternating fatigue testing.
8. Microscopical examination.

The results are given in graphical and tabular form and for testing No. 8 by photographs; they can be summarised as follows: Steels of tensile strengths between 76 and 82 tons/sq. in. containing 2·5% to 4/5% Ni with additions of tungsten and molybdenum gave no better figures than steels of the same tensile strengths with 1% to 2% Ni contents and additions of chrome and molybdenum, only the figures of nickel-free steel are somewhat lower; steels of tensile strengths of 57 to 63 tons/sq. in. with 1% to 2% Ni contents and even without Ni proved just as satisfactory as those with high Ni contents.

Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf. Volume XIX, issue 16.

Cationic Reagents in Flotation

CERTAIN compounds that have been used as stains by the biologists and dyes by the textile industry are examples of cationic compounds that have now been shown by R. S. Dean, J. B. Clemmer, and P. M. Ambrose,* to be effective reagents that may be used in the flotation process to increase the value of various ores. By selecting the proper reagent and by regulating the *p*H of the pulp being treated, a wide variety of ores may be treated. Quartz has been floated from hæmatite, and chromite and sulphides from their siliceous gangue. Also, quartz was floated from feldspar, from kyanite, and from spodumene.

Steel-Cored Aluminium Conductors

Unanimous agreement appears to have been reached regarding the use of steel-cored aluminium conductors for overhead lines. At the recent International Electro-Technical Commission meeting it was agreed to define annealed aluminium as aluminium which, in the form of wire of 1 mm. diameter and greater, has a maximum tensile strength of 9·5 kg. and a minimum elongation of 20% in a length of 200 mm., the measurement of the elongation to be taken after fracture. The normal resistivity value should be 0·0278 ohm. mm.²/m. at a temperature of 20° C. The density of annealed aluminium was agreed at 2·70 at 20° C., and the coefficient of variation of resistance with temperature at 0.004 per deg. C.

Hard-drawn aluminium was defined as aluminium which, in the form of wire of 1 mm. diameter and greater, has a minimum tensile strength of 15 kg./mm.²; the normal resistivity value shall be 0·0284 ohm. mm.²/m. at a temperature of 20° C. The temperature coefficient and density for hard-drawn aluminium are taken to be the same as for annealed aluminium. With regard to the steel core, it was agreed to adopt a minimum tensile strength of 120 kg.ämm.₂ and an elongation of 5% for wires of 3 mm. diameter and over, and 4% for wires which are smaller than 3 mm. diameter.

* "Progress in the Use of Cationic Reagents in Flotation." *Mining and Metallurgy*, June, 1938.

Reviews of Current Literature

Nickel Silver Alloys

THE results of a survey of available information on nickel silver alloys are given in this Research Report. The author, T. F. Pearson, M.Sc., gives a short introductory section, following which the specifications for nickel-silver alloys issued in various countries are listed and discussed. The mechanical and physical properties of these alloys, their values for mechanical properties in both cast and wrought forms at various temperatures, and their endurance properties are noted. Data on physical properties includes thermal conductivity and electrical resistance, density, resistance to tarnishing, shrinkage and fluidity. In the next section considerations of melting and casting are dealt with, and some of the casting defects are mentioned. There is a short mention of sands and sand moulding.

In the section dealing with the effects of impurities on behaviour and working such impurities as lead, tin, manganese, aluminium, iron, silicon, carbon, phosphorus, magnesium, sulphur, oxygen, antimony and arsenic are considered. Accounts of working the alloys—rolling, extrusion, jointing, cleaning and finishing—are given, together with notes on the effects of annealing.

The book is concluded with a bibliography of nearly 90 items, and to these reference is made throughout the text.

Research Report R.R.A. 472. Published by British Non-Ferrous Metals Research Association, Regnart Buildings, Euston Street, London, N.W. 1. Price, 3s. net.)

Modern Furnace Technology

THE theory and practice of furnaces, the art of building and using furnaces, are associated with industrial progress. Through almost every period, and long before the mechanical age, furnaces have been used, though often in a very primitive form ; but the rational design of furnaces with a view to economical operation is of quite recent date. It is not surprising, therefore, that considerable diversity in furnace construction and operation exists in particular metallurgical industries, not only as practised in different countries, but also within the same country. Some of these differences are due to local conditions, others to differences of opinion, and, while these differences will continue to exist, a sound knowledge of the principles involved will assist the designer in formulating his opinions on scientific lines which can be applied to suit particular conditions. It is the able manner in which these principles are described and discussed which makes this book a noteworthy contribution to the literature on this subject, and it will be especially valuable to furnace designers and operators.

Metallurgical work is most commonly performed at high temperatures, and although electric furnaces are now often employed, the combustion of fuel usually supplies the necessary heat, the thermal efficiency of the operation, the temperature attained, the design of the furnace, and other matters which are influenced by the amount of air supplied for combustion and the composition and volume of gases resulting, are all matters of vital importance in economical operations. In the design of furnaces it is desirable to ensure a high efficiency—that is, to make the maximum possible use of the heat resulting from combustion—for which purpose it is necessary to be able to estimate fuel requirements and also the determination of furnace efficiencies and have a working knowledge of the general thermal processes involved in the work for which a particular furnace is to be designed.

In this book the author explains the scientific principles underlying the various phases of modern furnace design and operation, and shows how these principles may be applied to achieve operating improvement. The more complex aspects of the subject are presented in the simplest possible manner, and the simplified methods of calculation adopted will be especially helpful in providing busy technical men with speedy, yet accurate, means of solution. Apart from the introduction, in which the elementary use of atomic weights is discussed, the various chapters deal with combustion and available heat, process balance-sheets, theory of gas flow, principles of heat transfer, the practical solution of heat transfer problems, heat exchangers, refractory materials, and physico-chemical considerations. At the end of practically each chapter is given a very informative summary of the particular subject discussed in the chapter.

The efficiency of a furnace depends upon its correct design and operation, and it is of great importance to have a fundamental basis for laws which govern the production and also practical formulas by which details of a furnace can be readily calculated. Most readers will find the principles and operations described in this book easily applicable to their own particular problems, and the author is to be congratulated on the production of so useful a work.

By H. ETHERINGTON, B.Sc., A.R.S.M. (Published by Charles Griffin and Co., Ltd., 42, Drury Lane, London, W.C. 2 ; price 30s. net.

Spectrochemical Abstracts, 1933-1937

THIS book contains a bibliography with short abstracts of 228 papers on spectrochemical analysis. The substances examined include biological material, earths, electrodes, gases, industrial materials, liquids, metals and alloys, minerals, non-metals, oxides and precipitates ; whilst apparatus and methods are also referenced. It also includes authors and references arranged alphabetically under the authors' names, and a list of books on spectrum analysis.

One very interesting abstract is that dealing with "Internal Standard," by Henri Triché, a method which can be applied to the analysis of aluminium-magnesium alloys ; another, by the same author, deals with calcium and barium in light alloys and solutions. The method described in that paper is one in which a high-frequency spark is passed between the alloy containing the calcium and a solution of barium chloride ; equality of intensity of 3,922·67 Ca and 3,891·78 Ba is obtained with a ratio Ba/Ca = 130. Taking the intensity of the Ca line as unity, the intensity of the Ba line has been studied as a function of the temperature of the solution and of the HCl concentration.

Compiled by F. TWYMAN, F.Inst.P., F.R.S. (Published by Adam Hilger, Ltd., 98, St. Pancras Way, London, N.W. 1. Price 3s. 10d.

Copper Pipe Lines

THIS practical handbook gives complete information on all matters relating to the design and installation of copper pipe lines in buildings. A great deal of the information is of a strictly practical nature, and is intended for those engaged in the actual installation of such copper pipe line services, but other chapters deal with the factors that must be considered by those who are concerned with the design and layout of such installations.

The book is lavishly illustrated with photographs, diagrams and charts and contains much useful tabular matter. The advantages of copper in regard to corrosion resistance, strength and ductility, and smoothness, are described in the introduction, and the ten chapters are divided into the following aspects :—copper tubes—heavy and light gauge—jointing methods for light gauge copper tubes (an extremely well illustrated chapter), the bending of copper tubes, copper tube fitting and the designing of pipe sizes including expansion joints and the setting out of bends, cold water services, the use of light gauge copper for hot water supply, heating installations, sanitation, gas fitting, and copper electrical conduit.

The second chapter, on jointing methods, includes description of the main types of compression joints and

their qualities, flared and plain end tubes, gland types and the method of numbering ends when ordering fittings, the general principle of capillary joints and practical advice on handling, also silver soldering, brazing, bronze welding and copper welding. It is pointed out that the rapid development in bronze welding has been largely due to the establishment, by experiment and research, of the correct composition and sizes of bronze and brass filler rods. It has been found, for instance, that the addition of a small quantity of phosphorus or silicon to the metal of the rod is of great assistance in preventing oxidation when the joint is made. Phosphor bronze (copper 95%, tin 4·5%, phosphorus 0·5%) and brass containing about 60% copper, 40% zinc, with phosphorus or silicon additions, are two alloys widely used as filler rods.

In addition to this comprehensive chapter, further details of the preparation of swept junctions are given in the chapters on heating and sanitation.

This book is published by The Copper Development Association, Thames House, Millbank, London, S.W.1, and is available without charge to those of responsible status or having genuine interest.

Fuels and Furnaces for Industrial Heating

SCIENTIFIC control of heating processes is becoming more and more widely adopted, but there is no doubt that reliance upon individual judgement and skill is still common in a number of factories. It is axiomatic, therefore, that a fuller understanding of the processes of combustion, of fuel characteristics, and the design of furnaces, by the operatives concerned would enable better results to be obtained in less time and at less cost, and this handbook should fill a very useful purpose.

It is one of the Industrial Textbooks series edited by Dr. Percy Longmuir. The opening chapter deals with combustion and this subject is analysed to explain clearly chemical reaction, the laws of combustion, heat transference, measurement of heat, specific heat and the laws governing gases. In this same chapter the principles of chemistry, applied to combustion, are explained simply and well, and form a basis by which the other chapters of the book would be intelligible even to the uninitiated. The other five chapters are devoted to fuels—that dealing with coal and coke being separated from the chapter which gives very full information on gas fuels, flame propagation and temperature, blast furnace gas, producer gas, water gas, town and coke-oven gas, mixing conditions, and oil fuel—furnace design, fuel control and economy, and gas producers.

Under furnace design the factors of thermal efficiency, standard performance and characteristic control curves are discussed, and this is made of greater value by the inclusion of details of instruments and furnace atmosphere, with a comparison of fuel costs.

Other features of value are considerations of rate of heating, size of furnace parts, the choice of appropriate fuel, dampers and gas burners and insulation bricks, together with equally clearly written information on heat recovery by regeneration and recuperation.

There are thirteen diagrammatic illustrations and three useful tables, whilst the various formulæ and analyses throughout the text add to the utility of this publication.

The final chapter, on gas producers, should be of interest in particular to works metallurgists and open-hearth steel melters, and the whole book should prove valuable to managers and foremen or furnace firemen in forge and heat treatment shops. The book should interest those concerned with industrial furnace firing, whether by solid or pulverised coal, oil fuel, or by any type of commercial gas.

By H. C. ARMSTRONG, M.Inst.C.E., F.Inst.F. Published by Chas. Griffin & Co. Ltd. 42, Drury Lane, London, W.C. 2. Price 4s. net.

Anodic Oxidation of Aluminium and Aluminium Alloy Parts

THE revised D.T.D. Specification 910A not only takes cognisance of the Bengough and Stuart process but of proprietary processes approved in writing by the Director of Technical Development. It describes the preparation of work, gives details of the Bengough and Stuart electrolyte and the nature of the cathodes and treatment of the parts by immersion for the same process. The inspection requirements specify that apart from the method giving results satisfactory to the Director of Scientific Inspection, the film immediately after washing and drying as specified, must be such that when dyed with methyl violet dye, vigorous rubbing with a damp cloth does not produce any loss of colour. The dye must be applied either by using violet endorsing ink on a rubber pad or by copying ink pencil rubbed over a moistened surface.

As in the Specification replaced, the process is declared not suitable for composite parts embodying metals or alloys other than aluminium and its alloys.

Catalogues and Other Publications

Sands, Clays and Minerals

A recent book by Sir George Paish, "The Way Out," is the subject of editorial comment in the current issue of *Sands, Clays and Minerals*, and the relation of Empire minerals to world affairs is discussed from a scientific point of view—an article which certainly provides food for thought. The history, occurrence, extraction and application of tantalum and niobium are dealt with at length by R. Genders, M.B.E., F.I.C., D.Met.; magnesium is also dealt with on an historical basis, followed by a review of production methods and applications—die-castings, wrought alloys, in powder form, extrusions, and the various commercial alloys; this latter being by L. Sanderson.

The selection of coal for industrial purposes is considered, and the results tabulated, by G. W. Himus, Ph.D., M.I.Chem. E.; there is an interesting and illustrated article on early technical balances; a review of the progress of mining in British Columbia, by John F. Walker (Deputy Minister of Mines), and a comparatively short but very informative treatise on powder metallurgy by W. D. Jones, M.Eng., Ph.D., in which he considers the porosity and hardness of compacted metals.

Contents also include articles on the minin industry ing Uganda and the arsenic industry in Devonshire.—Vol. III, No. 3, published by A. L. Curtis, Westmoor Laboratory, P.O. Box, 61, Chatteris, England, price 3s. 6d.

Two new publications have been issued by the British Aluminium Co. Ltd., these being "Aluminium Annealing and Heat-Treatment" and "Aluminium Jointing."

The first deals with general principles of annealing for aluminium, with specific data such as "the use of a high temperature reduces the time required for softening, but there is then a possibility that the annealing may be accompanied by deleterious changes in the physical structure of the metal, not readily detectable by tensile or elongation measurements, but which may affect the working properties of the metal.

The same book deals with heat-treatment considerations, plant, and baths and quenching; heat-treatment of wrought alloys—with a table of solution heat-treatment, quenching media and precipitation heat-treatment for four alloys; the heat-treatment of cast alloys—with a table of similar data for alloys BA/31, BA/34, BA/23, Hiduminium R.R. 50 and R.R. 53, and for "Y" alloy. (Publication 391 H).

The book on Aluminium Jointing covers oxy-acetylene welding for sheet, alloy castings, sections, and welding and jointing tubes in aluminium; electric welding, including spot welding, seam welding, butt welding, metallic arc welding and atomic hydrogen arc welding. Advice is given on soft and hard soldering, and also of the newly developed reaction soldering process in which the solder is a chemical mixture which is spread on the parts to be jointed and heated by a blow-pipe to about 200° C. A chemical reaction takes place which results in the deposition of pure zinc in a molten condition on the aluminium surfaces to be joined.

Corrosion Problems in the Sulphate Pulp Mill

Experience and recommendations for avoiding trouble are given, particularly with regard to metals and alloys used.

THE sulphate process of making pulp is not particularly complex, but compositions of the several liquors employed are very complicated and they vary from day to day and from one plant to another. This condition makes the investigation of corrosion problems exceedingly difficult. Most corrosion studies have, in fact, been carried out by the trial and error method, and the experience of mills has never previously been correlated and made available for the benefit of those interested.

In the sulphate process caustic soda and sodium sulphide are the principal chemicals. The cooking liquor is prepared by a causticising operation. Wood chips are dropped from overhead bins into steel digesters, and the cooking or white liquor is run in at the same time. Steam is applied and the contents brought up to about 100-110 lb. pressure (7 to 8 kg./cm.^{2}) at 344° F. (173° C.). When cooked, the pulp is blown into receivers, where as much as possible of the valuable soda is recovered, while the pulp is washed and prepared for shipment or use. The recovered cooking or black liquor is passed into evaporators for concentration and is then burned in furnaces to remove organic matter. When the sodium sulphate in the black liquor is incinerated, the carbon reacts with it, reducing a portion to sodium sulphide. The resulting black ash is a mixture of sodium carbonate, sodium sulphide and sodium sulphate, with small quantities of other sodium-sulphur compounds.

Black ash and added salt cake are fed into a furnace or smelter from which they pour in a molten stream into tanks of water. The solution is known as green liquor. The analysis of this liquor varies greatly, even in successive batches. In the sulphate process it will contain, in addition to sodium carbonate, sodium sulphide, sodium sulphate, sodium sulphite, sodium thiosulphate, polysulphides of sodium, sodium silicate, sodium aluminate and salt. The green liquor must be causticised before it can be used for cooking pulp. The treated liquor is known as white liquor.

The abrasive effect of the wood chips, and other solid particles in the liquors complicate the corrosion problem; some engineers in the industry believe that abrasion is as severe as corrosion. The experiences and recommendations of many mill engineers for avoiding trouble are given by Lee[1]. Some digester shells pit rather badly, on the other hand some have had a life of 20 years or more and show no pitting. A wrought steel shell is pitted but in use after 20 years. A shell of rimming steel boiler plate is pitted, although in use only 12 years. Pitting has been particularly bad around welds. In one case an $\frac{1}{8}$ in. plate of 18–8 chromium-nickel steel has proved successful in combating the combined corrosive and abrasive action encountered in the bottom of the digesters.

Diffusers and wash-pans have been in service from 3 to 25 years. In several cases corrosion has been most pronounced in false bottoms. The materials that have shown most resistance to pitting are Monel metal and low-carbon steel. Cast iron and cast steel are reported to pit badly. In several cases, steel or corrosion-resistant metal perforated screens used in diffuser bottoms has given no trouble. Metal found to combat corrosion at the steam and liquor inlets and outlets on digesters are stainless steel, forged steel, Ni-resist, and Monel metal. Steel tubes in indirect heaters are reported to have lasted less than a year. Some mills report stainless steel to be satisfactory.

Monel metal and stainless steel are reported as giving the best results in resisting corrosion in evaporated tubes, these materials are said to scale least. Where black liquor is handled with pumps, the most satisfactory metals to use for pistons and piston rods are reported to be Monel metal, 18–8 stainless steel and Ni-resist. In the washing of kraft pulp on vacuum filters, nearly every mill reported Monel metal best suited for the wire cloth. Materials considered best for pumps handling condensate from multi-effect evaporators are 18–8 stainless steel, Monel metal, and acid-resisting bronze.

The materials found to be best suited for conveying vapours given off from contaminated condensate, leaving evaporator, or from other vapours exuding from concentrated liquor tanks, diffusers, smelting furnaces, etc., varied somewhat. For piping, steel, stainless steel and cast iron were reported satisfactory. For ducts, steel, stainless steel, iron, galvanised iron and brick with asphalt covering were preferred. For pans, Monel metal and stainless steel were favoured. Cast iron, stainless steel and high silicon iron were reported as the best materials for pumps handling chlorine liquor. For bleach liquors, rubber lining or stainless steel were said to be best.

Corrosion in the Distillation of Fatty Acids

The original fats and resins present in pine wood, saponified by the action of the caustic cook liquor during digestion of the pulp in the manufacture of kraft paper, are recovered from the waste liquor and the washings by evaporation of the liquors and subsequent separation of the saponified fats and resins from the concentrated liquor, attended by framing, priming, caking and corrosion. In an effort to find a metal or alloy that would be resistant to the corrosive action of the crude fatty acids, an investigation has been carried out by Vilbrandt and Ward[2] on a series of 24 commercial metals and alloys, embracing almost every available type of metal and alloy used in still construction.

In the test runs as performed, it was attempted to duplicate as nearly as possible conditions which would be encountered in actual plant practice. However, there are certain facts which must be considered before any but relative interpretations can be placed upon the results. The first and most important of these considerations is that the fatty acids were continuously decomposed by destructive distillation during the tests. This is evidenced by the drop in the acid value of the crude fatty acids during the course of each test. The acid values dropped from 142-146 to 90-102 at the end of the 24-hour run and to 55-62 at the end of the 72-hour run. This would indicate that the corrosion rates as shown are of a lower value than would be expected in plant practice where the metals would be continuously subjected to the action of fresh material. The other factor, and one that is much more difficult to evaluate, is the effect of heat transmission through the metal itself, as would be the case in actual practice. In the case of the test runs, heat was supplied to the specimen from the fatty acid itself; this may or may not have an effect on the corrosion rate.

The results of these tests showed that crude fatty acids corroded all alloys and metals to a very marked extent, with the exception of the stainless steels containing not less than 20% chromium and nor less than 9% nickel. The most suitable alloys of the stainless steel group for structural material for fatty acid stills seem to be the iron alloys containing high chromium and nickel content, or those with a smaller percentage of chromium and nickel, but alloyed with molybdenum. The most resistant alloy was an 18–8 chromium-nickel alloy with 3% molybdenum.

1 James A. Lee. 73rd General Meeting Electrochemical Society. Preprint 31.

2 F. C. Vilbrandt and L. E. Ward, Jn. 73rd General Meeting of Electrochemical Society. Preprint 21.

Business Notes and News

Mauretania Launch

A Memorable Occasion

Much interest is attached to the launch of the new 33,000-ton Cunard White Star liner, *Mauretania*, from Cammell Laird's shipyard at Birkenhead, on July 28, and preparations for the great spectacle are almost completed. The ceremony is to be performed by Lady Bates, wife of the chairman of the Cunard White Star Company. Arrangements have been made to broadcast the ceremony at 12-15 p.m. and it is noteworthy that later a programme will be given featuring the old Tyne-built *Mauretania*, which, for twenty-two years held the Blue Riband of the Atlantic.

With the launching of this vessel a new chapter will be opened in the history of transatlantic passenger traffic, and it is confidently expected that she will, at least in some measure, take the place held so long with honour by the old *Mauretania*.

Anglo-German Agreement

The Anglo-German Loans Agreement, by which Germany has agreed to honour the Austrian guaranteed loans in full, marks the end of the negotiations between the two Governments which at one time seemed on the verge of breaking down. It is noteworthy that the agreement is restricted to British holders, and is without prejudice to the question of legal liability.

The basis of the agreement, of course, is the absorption of Austria's debt into that of the Reich, and the reduction of the interest rates on the Dawes and Young loans. Only the service of the Austrian 3% and 4½% guaranteed loans remains unchanged—the German Government apparently regards 4½% as a " reasonable " rate to pay, and one consistent with the prestige of a great nation. The Dawes loan and the Austrian 7% of 1930 now rank together, receiving 5% interest, the cut sweetened by a 2% sinking fund. The Young loan and Saarbrucken loan have their rate of interest cut to 4½%, but here again the cut is sweetened by the 1% sinking fund, which is to be begun after two years. The service of the Konversionskasse bonds and the Austrian Government Credit Anstalt bonds remains, of course, as before.

The most satisfactory feature of the new agreement, as a whole, is that it seems to indicate Germany's good faith in the honouring of her debts and with this in view the way will probably open for better trade relations between Britain and Germany.

Tin Consumption Analysis

Consumption statistics for the United Kingdom and the U.S.S.R. are available* for five months of this year, and show a decline of 20% in the United Kingdom to 8,251 tons and an increase of over 44% in Russia to 9,090 tons, comparison being made in each case with the corresponding period of 1937. The fall in tin consumption this year has been most severe in the United States, where the total for the first four months has decreased by 45% from 33,050 tons in 1937 to 18,187 tons in 1938. In Germany there was an increase of 7·3% to 4,291 tons in January–April, 1938, and in France a decrease of 6·7% to 3,368 tons. Consumption in Japan increased by 23·7% to 3,710 tons and in Italy by 34·4% to 1,697 tons. Other important increases occurred in British India, Sweden, Switzerland and Poland, while there were decreases in Canada, Belgium, Holland and Czechoslovakia.

Consuming Industries

World tinplate production in the first four months of 1938 totalled 910,000 tons, showing a decrease of 38½% as compared with the total of 1,478,000 tons for the corresponding period of 1937. Production in May, 1938, is estimated at 223,000 tons, against 394,000 tons in May, 1937. The output of the world motor industry decreased by nearly 41% from 2,301,000 vehicles in January–April, 1937, to 1,365,000 vehicles in January–April, 1938. It is estimated that the output for May, 1938, was only 325,000 vehicles, compared with 655,000 vehicles in May, 1937.

* International Tin Research and Development Council's Bulletin; June issue, published by the Hague Statistical Office.

Long Service Presentations

At the Metropolitan-Vickers Club on July 11, Sir Felix J. C. Pole, on behalf of the Metropolitan-Vickers Electrical Co., presented each of 105 employees who had completed 35 years' service on December 31, 1937, with a watch or clock. This mark of appreciation was received by three directors and a number of managers of departments as well as by staff and workpeople. The number includes four women employees. The choice of watch or clock was left to the individual, and 46 eight-day Westminster chiming clocks, 56 gold demi-hunter pocket watches and three ladies' wrist watches all suitably inscribed were distributed.

Iron and Steel Production

There is a tendency to take a little brighter view of the trends in the iron and steel industry. It is true that the first five months of the year showed a decided falling off in production and that, in certain sections, from a condition of scarcity stocks have risen to such a high level that production has been held up. This is noteworthy in the case of pig iron, the amount in stock being well above what may be considered as normal reserve. The trouble is probably due to the amount of pig iron imported at the time when it would have been profitable to re-apply the duties. So many manufacturers were put to considerable inconvenience by shortage of home supplies a year ago, that they can be excused getting stocks from abroad when the opportunity presented itself, and although stocks of foreign pig iron are still considerable, the time is rapidly approaching when consumers will again rely solely upon home sources of supply.

Although there has been a decline in the demand for steel goods, there has been a rapid advance in the home demand for steel plate, this applying particularly to thin sheets absorbed by the motor industry. But this industry does not represent the only avenue through which sheet consumption has increased. Building construction, office appliances and equipment, domestic fittings, and expansion in the use of tin plate by the food and dry goods packing industries have accounted for much of the increase in sheet steel consumption. The stock position regarding steel goods is difficult to assess, and there is little doubt but that over-ordering was a factor that has influenced the market, and excess stocks are now being drawn upon at the expense of present production. This indicates that the position is not actually as adverse as might appear at first glance.

The market for heavy rails has decreased but special steels have accounted for a substantial improvement, although it must be remembered that the rearmament programme has influenced much of the special steels trade. Stainless and corrosion-resisting steels of the chrome-nickel, austenitic classes have found increasing applications in many industries, including boiler making, furnace building, and for components of petrol and compression ignition engines.

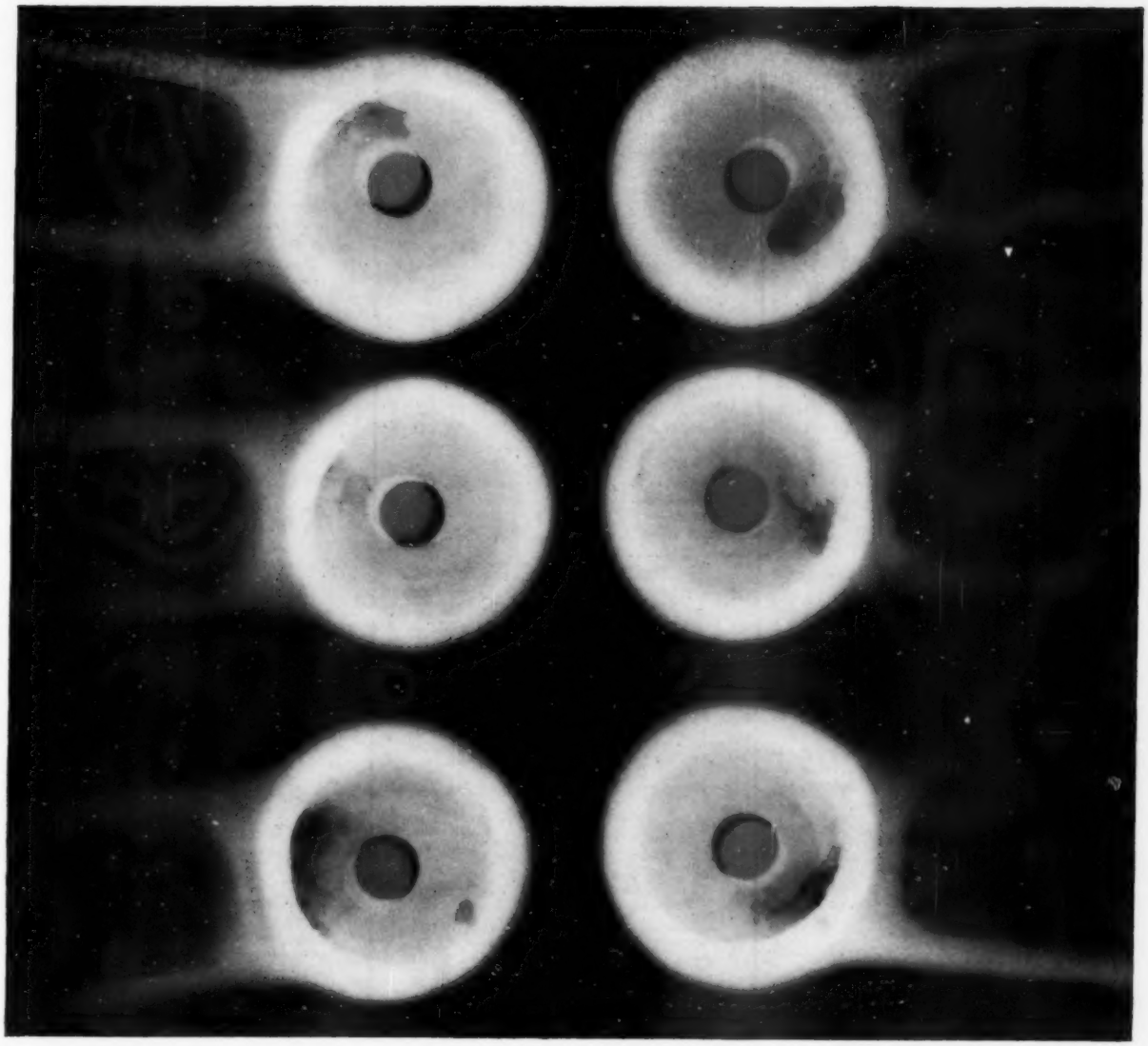
The application of steels to a greater diversity of purposes should more than counteract the apparent tendency to consumption decline, and show that the present position is more in the nature of a passing phase.

Personal

Dr.-Ing. h. c. Wolfgang Reuter, General Manager of Demag Aktiengesellschaft, Duisburg, Germany, last month celebrated his industrial jubilee.

It is just fifty years since he began his career in the crane works of Stuckenholz at Wetter-Ruhr. When Bredt, head of Stuckenholz, retired in 1899, Dr. Reuter became sole proprietor. Seven years later he amalgamated the business with the neighbouring firm of Markische Maschinenbau-Anstalt, he himself becoming manager. In 1909 he went a step further; he arranged a working arrangement with its chief competitors—The Benrather Maschinenfabrik A.G. in Beqrath and the Duisburger Maschinenbau-Aktiengesellschaft, vorm. Becham and Keetman in Duisburg. A year later amalgamation was completed under the name of " Deutsche Maschinenfabrik A.-G. Duisburg," now world-famous as " Demag," with Dr. Reuter, of course, as General Manager.

Dr. Reuter has received many honours. One of them—his doctorate—was conferred on him in 1919 by the Technical High School of Aix-la-Chapelle in recognition of his services in the development of cranes for iron and steel works.



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Only when subjected to X-ray inspection did it become apparent that each casting was defective—utterly unsuitable for the use for which it was intended. X-ray showed, too, that the defects were of the same type and in practically the same positions in each of the castings. The need: an improvement in foundry technique to eliminate defects that would have continued with the faulty procedure.

With the change in procedure guided by X-ray inspection, perfect castings were soon made available. The manufacturer, the foundry's customer was satisfied that he could market his product with full confidence in its strength and dependability.

Whether the castings you want to inspect are large or small, regardless of the metal, Victor X-Ray Corporation can furnish the X-ray equipment that is exactly suited to your requirements. And a staff of experienced engineers stands ready to help you solve X-ray inspection problems. For full information on equipment and procedure, address Dept. LU, Victor X-Ray Corporation Ltd., 15, Cavendish-place, London, W.1.

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ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£74	10	0
Chinese		48	0	0
Crude		30	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11
Brazed Tubes	,,	0	1	1
Rods Drawn	,,	0	0	8½
Wire	,,	0	0	7½
*Extruded Brass Bars	,,	0	0	4½

COPPER.

Standard Cash		£39	16	6
Electrolytic		44	15	0
Best Selected		44	0	0
Tough		39	15	0
Sheets		76	0	0
Wire Bars		45	5	0
Ingot Bars		45	5	0
Solid Drawn Tubes	lb.	0	1	0
Brazed Tubes	,,	0	1	0

FERRO ALLOYS.

‡Tungsten Metal° Powder. nominal	lb.	£0	4	9½
‡Ferro Tungsten° nominal	,,	0	4	8
Ferro Molybdenum°				
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL 2–4% Carbon, scale 12/– per unit	ton	34	15	0
NOMINAL 4–6% Carbon, scale 8/– per unit	,,	24	5	0
NOMINAL 6–8% Carbon, scale 7/6 per unit	,,	24	0	0
NOMINAL 8–10% Carbon, scale 7/6 per unit	,,	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon. scale 13/– per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/– per unit	,,	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25–50%	,,	0	14	0
§Spiegel, 18–20%	ton	11	0	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	12	0	0
45/50% basis 45%, scale 5/– per unit	,,	12	10	0
70/80% basis 75%, scale 7/– per unit	,,	17	0	0
90/95% basis 90%, scale 10/– per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	18	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	0	0
Scotland	—	2	0	0
Durham	—	1	14	6
Furnace Coke—				
Scotland		1	15	0
S. Wales	—	1	9	0
Durham	—	1	7	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£62	0	0
*Commercial Ingots		47	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0	11
*Cored Bars	,,	0	1	1

MANUFACTURED IRON.

Scotland—				
Crown Bars,		£13	10	0
N.E. Coast—				
Rivets		12	15	0
Best Bars		15	15	0
Common Bars		12	10	0
Lancashire—				
Crown Bars		13	10	0
Hoops		14	2	6
Midlands—				
Crown Bars		13	10	0
Marked Bars		15	15	0
Unmarked Bars			—	
Nut and Bolt Bars		11	15	0
Gas Strip		14	2	6
S. Yorks.—				
Best Bars		15	15	0
Hoops		14	2	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	0	11
*Cored Bars	,,	0	1	1
†Strip	,,	0	0	10½
†Sheet to 10 W.G.	,,	0	0	11
†Wire	,,	0	1	0½
†Rods	,,	0	1	0
†Tubes	,,	0	1	6¼
†Castings	,,	0	1	3

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £32 above English Ingots.

PIG IRON.

Scotland—				
Hæmatite M/Nos.		£6	13	0
Foundry No. 1		6	0	6
,, No. 3		5	18	0
N.E. Coast—				
Hæmatite No. 1		6	13	0
Foundry No. 1		5	11	6
,, No. 3		5	9	0
,, No. 4		5	8	0
Silicon Iron			—	
Forge		5	8	0
Midlands—				
N. Staffs. Forge No. 4		5	8	0
,, Foundry No. 3		5	11	0
Northants—				
Foundry No. 1		5	11	6
Forge No. 4		5	5	6
Foundry No. 3		5	8	6
Derbyshire Forge		5	10	0
,, Foundry No. 1		5	14	0
,, Foundry No. 3		5	11	0
West Coast Hæmatite		7	4	8
East ,, ,,		7	3	6

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Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.
Per English ton Kr.195

Billets, single welded, over 0·45 Carbon.
Per metric ton Kr.335-385
Per English ton £17 11 3/£20 3 9

Wire Rods, over 0·45 Carbon.
Per metric ton Kr.375-405
Per English ton £19 12 2/£21 4 9

Rolled Martin Iron, basis price.
Per metric ton Kr.230-250
Per English ton £12 1 2/£13 2 2

Rolled charcoal iron, finished bars, basis price.
Per metric ton Kr.360
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f.o.b. Gothenburg.

SCRAP METAL.

Copper, Clean		£32	0	0
,, Brazery		29	0	0
,, Wire			—	
Brass		22	10	0
Gun Metal		32	0	0
Zinc		8	0	0
Aluminium Cuttings		71	0	0
Lead		13	10	0
Heavy Steel—				
S. Wales		3	10	0
Scotland		3	6	0
Cleveland		3	7	0
Cast Iron—				
Midlands		3	5	0
S. Wales		3	10	0
Cleveland		4	2	6
Steel Turnings—				
Cleveland		2	12	6
Midlands		2	5	0
Cast Iron Borings—				
Cleveland			—	
Scotland		2	2	6

SPELTER.

G.O.B. Official			—	
Hard		£10	0	0
English		15	12	6
India		13	5	0
Re-melted		10	15	0

STEEL.

Ship, Bridge, and Tank Plates. Scotland		£11	10	0
North-East Coast		11	10	0
Midlands		11	10	0
Boiler Plates (Land) Scotland		12	0	0
,, ,, (Marine) ,,			—	
,, ,, (Land), N.E.Coast		12	0	0
,, ,, (Marine) ,,			—	
Angles, Scotland		11	0	6
,, North-East Coast		11	0	6
,, Midlands		11	0	6
Joists		11	6	0
Heavy Rails		10	2	6
Fishplates		14	2	6
Light Rails		10	7	6
Sheffield—				
Siemens Acid Billets		11	15	0
Hard Basic £6 17 6 to		10	2	6
Medium Basic, £6 12 6 and		10	0	0
Soft Basic		8	15	0
Hoops		11	15	0
Manchester Hoops		11	5	0
Scotland, Sheets 24 B.G.		15	15	0

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Finished Bars 14% Tungsten	lb.	£0	3	0
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Extras:				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to ⅛ in.	,,	0	1	0
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Flats under 1 in. × ⅛ in.	,,	0	0	3
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TIN.

Standard Cash		£194	0	0
English		193	15	0
Australian			—	
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Tin Plates I.C. 20 × 14 box		1	0	3

ZINC.

English Sheets		£29	10	0
Rods		20	0	0
Battery Plates			—	
Boiler Plates			—	

LEAD.

Soft Foreign		£15	8	6
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° McKechnie Brothers, Ltd., July 12. Subject to Market fluctuations.
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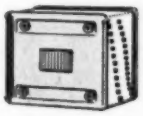
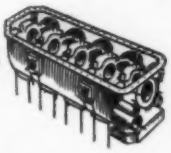
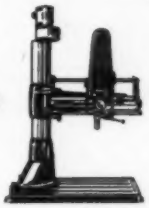
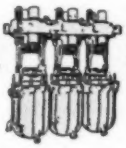
† C. Clifford & Son, Ltd., July 12. Buyers are advised to send inquiries for current prices when about to place order.
‡ Murex Limited, July 12
¶ The prices fluctuate with the price of Tungsten.

For ledger covers  and engine crankcases 

For miners' lamps and machine  tools

For portable typewriters and textile machinery

For electrical  switchgear and aircraft fairings

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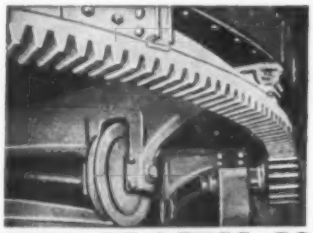

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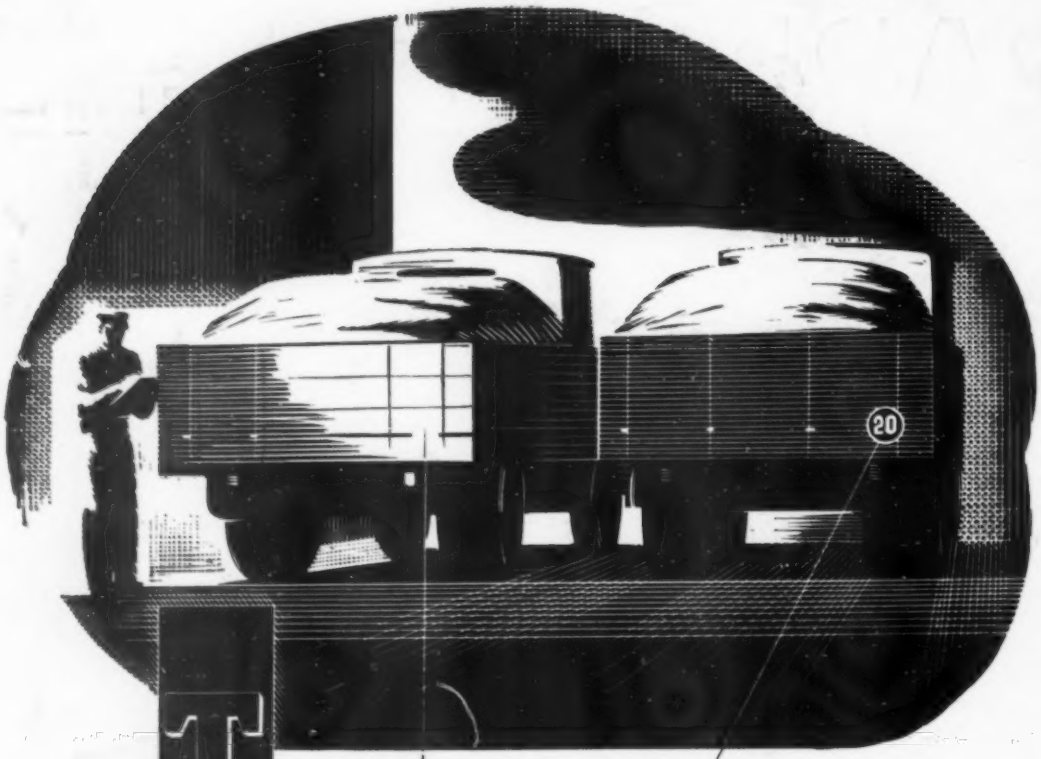

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